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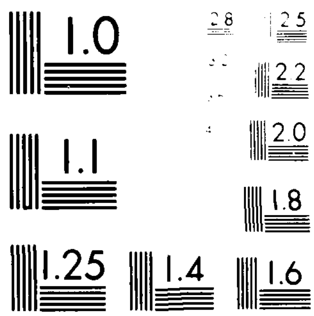

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FLOOD CONTROL APPENDIX

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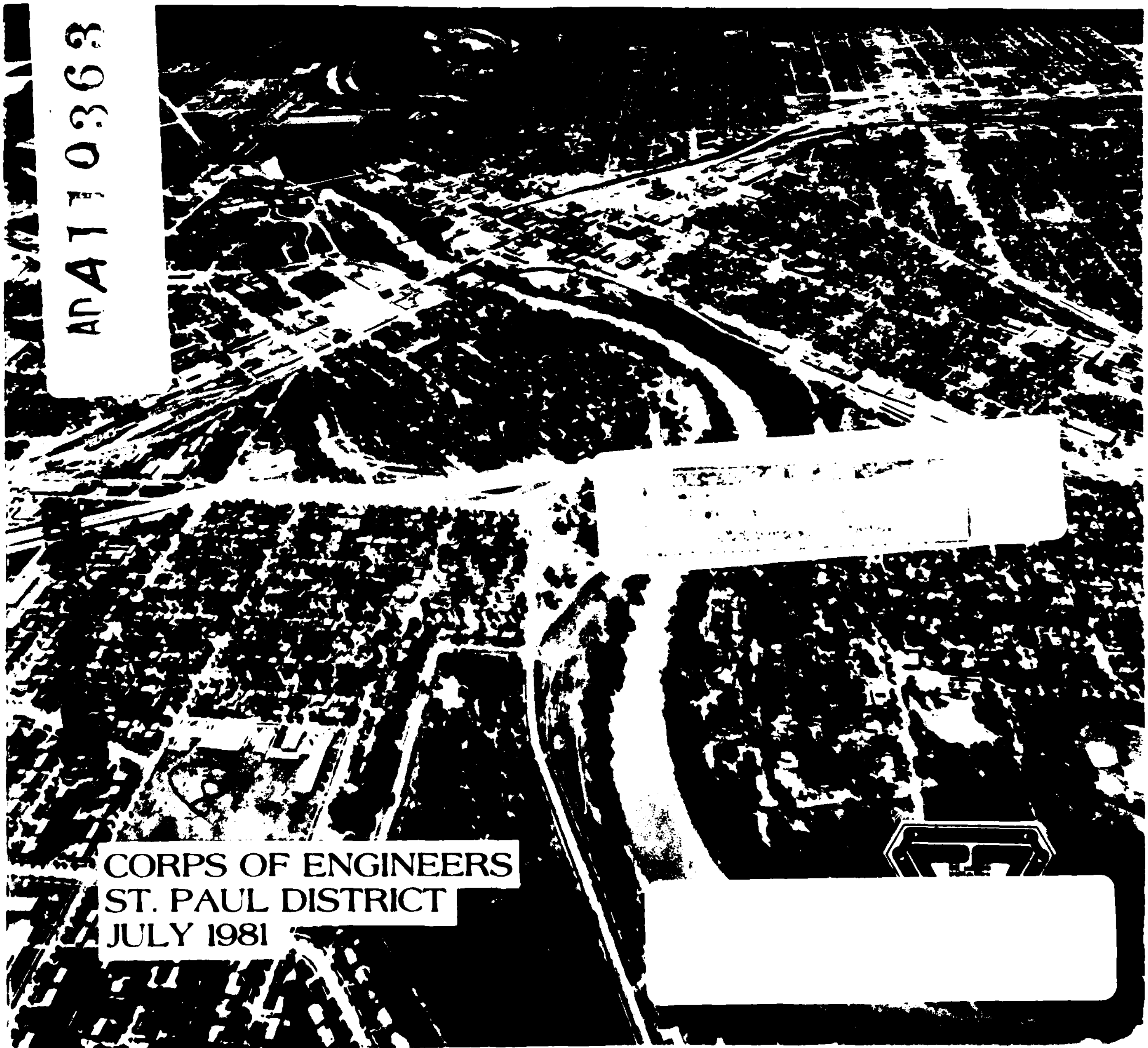

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Flood control studies showed that the East Grand Forks levee project authorized in 1953, but not constructed, still was economically feasible and recommended further study under the Corps' postauthorization program. Grand Forks flood control studies found four measures which qualified for further study and possible implementation under the Corps' Small Pro[illegible] Continuing Authority. An urban drainage master plan proposed for the developing fringe of the city would require future developments to incorporate

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ponding areas to temporarily store runoff to limit peak discharges, to those that occur under existing land conditions.

Becuase the flood control investigation was transferred from the urban study to the Section 205 authority, a detailed environmental impact assessment and possibility an EIS were also deferred. Similarly, the Corps developed the urban drainage master plan for Grand Forks as a planning service. and implementation of the plan are the prerogatives of the city and do not involve the Corps.

PREFACE

The Corps of Engineers Urban Study Program is aimed at providing planning assistance to local interests in a variety of water resource and related land resource areas, including water supply, wastewater management, flood control, navigation, shoreline erosion, and recreation. In areas of traditional Corps responsibility (such as flood control), the Corps may implement and construct projects shown feasible in the urban study. In other areas (such as wastewater management), Corps involvement carries only through the planning stage; findings are turned over to local interests for incorporation into their broad urban comprehensive planning effort. Implementation is at the discretion of local interests in conjunction with appropriate State and Federal agencies.

The St. Paul District, Corps of Engineers, conducted the Grand Forks-East Grand Forks (GF/EGF) Urban Water Resources Study, which was a cooperative effort between local, State and Federal agencies. The GF/EGF urban study spanned a time of transition in the Corps' urban study program. In mid-1978, directives were issued deleting the third and last stage of urban studies. At that time, the second stage of the GF/EGF urban study was nearing completion, but commitments for stage 3 studies had been made to local interests and involved State and Federal agencies. Therefore, the GF/EGF urban study was allowed to proceed to stage 3.

During the first stage, the 14-township study area was selected, broad topical problems to be addressed (water supply, wastewater management, and flood control) were identified, and a "plan of study" was developed. The plan of study outlined the general approach the study would follow. During stage 2, the topical problems were broken down into explicit problem areas. Investigators formulated a broad array of alternatives to resolve the study area's problems. The alternatives were evaluated to eliminate those which were not suitable or cost effective. The stage 3 study examined in detail those alternatives that passed the stage 2 screening. Alternatives were reassessed to determine their respective cost effectiveness and environmental/social impacts.

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This particular document is 1 of 11 constituting the GF/EGF urban study report:

Summary Report
Background Information Appendix
Plan Formulation Appendix
Water Supply Appendix
Wastewater Management Appendix
Flood Control and Urban Drainage Appendix
Flood Emergency Plan for Grand Forks, North Dakota
City of East Grand Forks, Minnesota, Civil Defense Flood Fight Plan
Energy Conservation and Recreation Appendix
Public Involvement Appendix
Comments Appendix

This appendix includes:

1. Stage 2 report
   - East Grand Forks floodplain management
   - Grand Forks floodplain management
   - Grand Forks urban drainage

2. Stage 3 report
   - Grand Forks flood control
   - Grand Forks urban drainage

The stage 2 and stage 3 reports have been combined to provide the reader with a complete sequential picture of the entire flood control study effort throughout the urban study. The reader may encounter repetitious or apparently contradictory materials. Such cases reflect the iterative analytical process which relied on an evolving data base.

Stage 2 studies showed that the East Grand Forks levee project authorized in 1953 but not constructed still was economically feasible using the originally authorized interest rate. It was recommended that the East Grand Forks flood situation be studied further under the Corps' Phase I General Design Memorandum program, rather than continuing as part

of the urban study. In October 1979, the recommended study was initiated. It is currently scheduled to end in April 1984.

Stage 2 studies also screened an array of flood control measures aimed at protecting Grand Forks or both cities. Measures that were not technically and economically feasible were eliminated; those deserving more detailed consideration in stage 3 were identified. In addition, Grand Forks' urban runoff problems were discussed and preliminary assessments were made of the potential of basic urban drainage systems.

The stage 3 flood control study focused on seven structural and nonstructural plans designed to protect local areas within Grand Forks and one structural plan that would protect both Grand Forks and East Grand Forks. Three of the nonstructural plans warranted serious consideration and had first costs low enough to qualify for further study and possible implementation under the Corps' Small Projects Continuing Authority (Section 205 of the 1948 Flood Control Act, as amended). The Section 205 authority offers the advantage of quicker implementation than the Corps' usual survey investigation which requires specific congressional authorization and funding.

In stage 3, the continuing urban runoff investigation culminated in publication of an urban drainage master plan for the developing fringe areas around Grand Forks. The recommended plan would require future developments to incorporate ponding areas to temporarily store runoff and limit peak discharges to those that occur under existing land use conditions.

Because the flood control investigation was transferred from the urban study to the Section 205 authority, a detailed environmental impact assessment and, possibly, an environmental impact statement were also deferred. Similarly, the Corps developed the urban drainage master plan for Grand Forks as a planning service; adoption and implementation of the plan are the prerogatives of the city and do not involve the Corps. Therefore, responsibility for environmental/social impact analyses would lie with the city and other participating agencies.

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The impact assessment discussion in this appendix should not be considered a definitive or final environmental/social impact evaluation of the alternatives and recommended plans. However, the discussion indicates areas of special concern that may require further study. Agencies involved in implementing any of the alternatives should comply with applicable requirements of the National Environmental Policy Act of 1969 (Public Law 91-190) and subsequent legislation.

The St. Paul District has completed a cultural resources literature search, records review, and reconnaissance-level survey of the area. Thirty-three historic and prehistoric sites were identified within the cities' limits. These sites should be considered during implementation, and project plans should be coordinated with the North Dakota and Minnesota State Historic Preservation Offices. Additional cultural resource surveys may be needed prior to construction.

Recreational opportunities and impacts on existing facilities should be considered in any implementation plans; for instance, trail systems might follow project rights-of-way.

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STAGE 2 FLOODPLAIN MANAGEMENT STUDIES AT EAST GRAND FORKS, MINNESOTA

STUDY AUTHORIZATION AND PURPOSE

The Grand Forks-East Grand Forks Urban Water Resources Study was an interim study, a part of the overall Red River of the North Basin Study which was authorized by a resolution of the Committee on Public Works, United States Senate, 93d Congress, 2d Session, adopted on 30 September 1974 at the request of Senator Quentin N. Burdick of North Dakota. The principal purpose of the urban study's investigation of flood damage reduction measures at East Grand Forks, Minnesota, was to review the adequacy and economic feasibility of a flood protection project authorized in the 1950's, but whose construction was deferred pending a satisfactory local cooperation agreement.

The authorized project evolved from basin studies conducted under the Flood Control Act approved 30 June 1948. The Flood Control Act approved 17 May 1950 authorized completion of plans developed in accordance with the 1948 Flood Control Act. The Definite Project Report on Red River of the North at Grand Forks, North Dakota-East Grand Forks, Minnesota, completed in May 1953, contained detailed designs for the Lincoln Park levee/floodwall project in Grand Forks, North Dakota (which was completed in 1958), and the East Grand Forks levee/floodwall project.

Construction of the East Grand Forks project was not initiated because no sponsor was willing to provide the necessary assurances of local cooperation. The authorizing acts provided that authorization would expire 5 years after the date on which local interests were notified in writing of the requirements of local cooperation, unless within that time satisfactory assurances of cooperation were furnished. Local interests were advised formally of the cooperation requirements in 1956 and the project was deauthorized in 1961 when the 5-year limitation was exceeded without action by the community. With the recurrence of serious flood threats in 1965, 1966, and 1969 and in view of changed financial conditions, the city indicated a desire to reactivate the project. The Flood Control Act

approved 31 December 1970 extended the expiration date of the original authorization until 1975 to allow local interests time to furnish the necessary assurances. East Grand Forks provided a satisfactory local cooperation agreement in 1975.

The Grand Forks-East Grand Forks urban study reevaluated East Grand Forks' authorized project to assess the relative merits of initiating a major reformulation effort under the Corps' postauthorization authority. In addition, the urban study considered the feasibility of flood barriers for areas north and south of the authorized project which have experienced extensive development since the 1953 report. The urban study's analyses were conducted by Wehrman, Chapman Associates, Inc., under contract and were based principally on existing information supplemented by a field inspection and discussions with East Grand Forks city officials.

PROBLEMS AND NEEDS(1)

East Grand Forks is located at the confluence of the Red River of the North and Red Lake River (Red River mile 298.0). Situated on the flat bed of former glacial Lake Agassiz, the city is subject to frequent flooding from both rivers. Flooding begins at a Red River stage of 28 feet (elevation 806.35 at the USGS (U.S. Geological Survey) gage, mile 295.7). Flood damages begin at a corresponding river stage of 35.6 feet (gage elevation of 813.95 and discharge of 27,000 cfs (cubic feet per second)). The corresponding 1-percent change flood stage would be 50.8 feet with a maximum discharge of 89,000 cfs. The record flood of 1897 reached a stage of 49.3 feet with a maximum flow of 80,000 cfs.

A large part of the urbanized area is subject to either direct (surface water) or indirect (sewer backup, etc.) flooding. Approximately 1,000 structures would be subject to direct flooding from the 100-year flood. Similarly, about 600 structures would be affected by indirect flooding. Major disasters were averted in the city during the 1965,

(1) The stage-discharge, frequency-discharge, and historic flood data cited in this stage 2 report were revised later in the urban study. Differences between these and later data reflect Corps efforts to refine the hydrologic and hydraulic data base. The stage 2 data are reprinted here to allow the reader to follow the original decision-making process.

1966, and 1969 spring floods through massive flood fight efforts including construction of emergency levee works. Without these measures, flood damages would have been about $2 million in 1965 and $2.4 million in 1966 and 1969. The recent 1975 summer flood resulted in damages of about $691,000 (January 1976 price levels). This figure included damage to residential, commercial, industrial, and public property; flood fight costs; and cleanup of city parks and other facilities. Under present conditions and prices, a recurrence of a flood similar to the record 1897 flood would result in damages of about $8,000,000.

The authorized project for East Grand Forks would protect about 50 percent of the developed area. However, continued urban expansion in the northern and southern portions of the city has greatly increased the flood damage potential. A mid-1975 survey of these unprotected areas indicated a total damage potential of about $734,000 (January 1976 price levels) to 88 residences if a 1-percent chance flood were to occur.

The highly developed central part of the city has a limited and uncertain measure of flood protection provided by an emergency levee system (see figure 1 and following photo). This system consists of emergency levees generally following the alignment of the authorized project. However, these levees were built in haste before or during past flood emergencies and as such were not built in accordance with Corps design criteria and construction procedures. In the event of a major flood, these levees are susceptible to failure and thus offer city residents a false sense of security. Assuming appropriate closures and no structural failures, these levees with 3 feet of freeboard would protect against the 25-year flood and reduce total potential flood damages by only 40 percent with remaining average annual economic flood losses estimated at $394,000. Further, the interior drainage features for this existing system are grossly inadequate. Substantial emergency pumping of seepage waters and trapped rainfall runoff has been and will continue to be required with the present levee system during floods.

Emergency Levee System

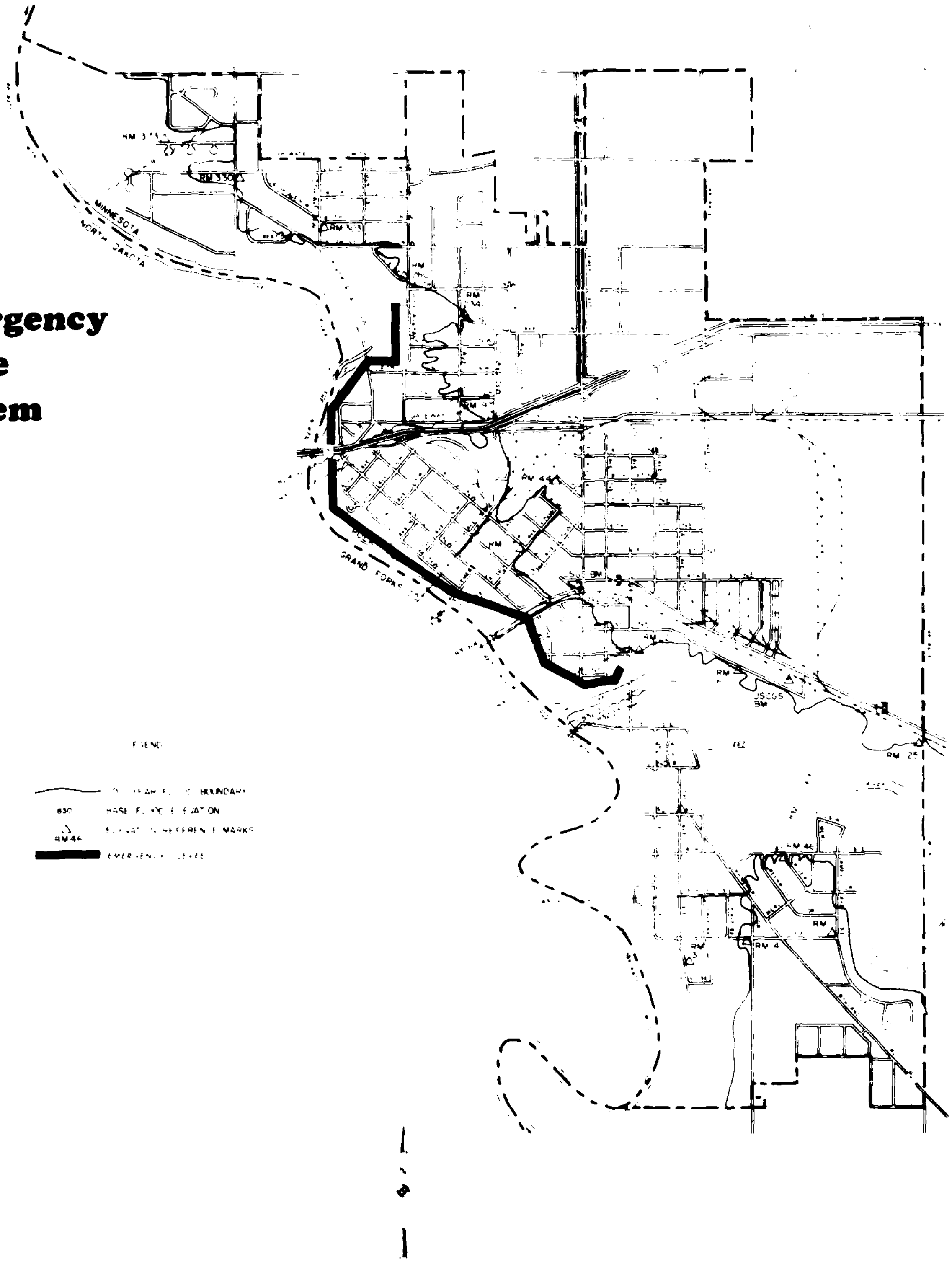

FIGURE 1

East Grand Forks

Minnesota

Emergency levee in East Grand Forks

A more serious problem affecting the provision of structural flood control measures for the city is the very unstable condition of the riverbank. A weak layer of lacustrine deposits deposited during the glacial Lake Agassiz period is present at a depth of roughly 50 feet throughout the area. This layer is about 30 feet thick in areas undisturbed by subsequent river erosion. In other areas, this layer has been completely replaced with fluvial deposits. Levees or other structures constructed in areas of undisturbed weak lacustrine deposits have resulted in severe slides. A damaging slide undergoing continual movement is located on the existing city levee just north of Sixth Avenue NW (figure 1). This slide has resulted in subsidence of the levee and damage to adjacent yards and residences. Another slide area showing continual slow movement is located in a parking lot just downstream of Demers Avenue. Thus, any contemplated raise or reconstruction of the existing emergency levees must be supported by detailed foundation studies.

East Grand Forks has entered the regular phase of the FIA (Federal Insurance Administration) flood insurance program. Ordinances to fully implement this program were adopted on 23 September 1977. However, local officials strongly believe that the Flood Hazard Boundary Map provided by the FIA is inaccurate in that it includes several areas which they believe are clearly not subject to either direct or indirect flooding or loss of access during major floods.

From the foregoing discussion, it is clear that, even with the emergency levee system, East Grand Forks remains subject to major economic losses, threats to public health and safety, and possible loss of life. Measures are needed to upgrade the level of protection, at least to be commensurate with existing local floodplain and flood insurance programs.

REEVALUATION OF AUTHORIZED PROJECT

As discussed in the preceding paragraphs, the existing emergency levee system is inadequate in construction, height, and possibly in extent. The authorized project (plan A on figure 2) would provide for raising and widening of 7,600 lineal feet of existing levee, 1,500 feet of concrete floodwall from between Seventh and Eighth Avenues NW to about Third Avenue NW, interior drainage works, a ramp over the levee at River Road NW, and necessary utility relocations. Plan A would protect against a peak flood stage 1 foot higher than the 1897 flood level which had a stage of 49.3 (1.6-percent chance flood and Q=80,000 cfs). Total Federal and non-Federal first costs for this plan are estimated at $6,858,000 and $479,000, respectively, based on October 1977 price levels. Corresponding annual charges at 3 1/4- and 6 5/8-percent interest rates and a 100-year economic life are shown in table 1. A detailed estimate of first costs for the authorized plan is included as Attachment A. Related average annual benefits of $316,000 are shown in table 2, which indicates that plan A is economically feasible at a 3 1/4-percent interest rate with a benefit-cost ratio of 1.2 based on existing condition damages only, i.e., no projected future growth damages. At a 6 5/8-percent interest rate, the corresponding benefit-cost ratio without future growth damages would be 0.6.

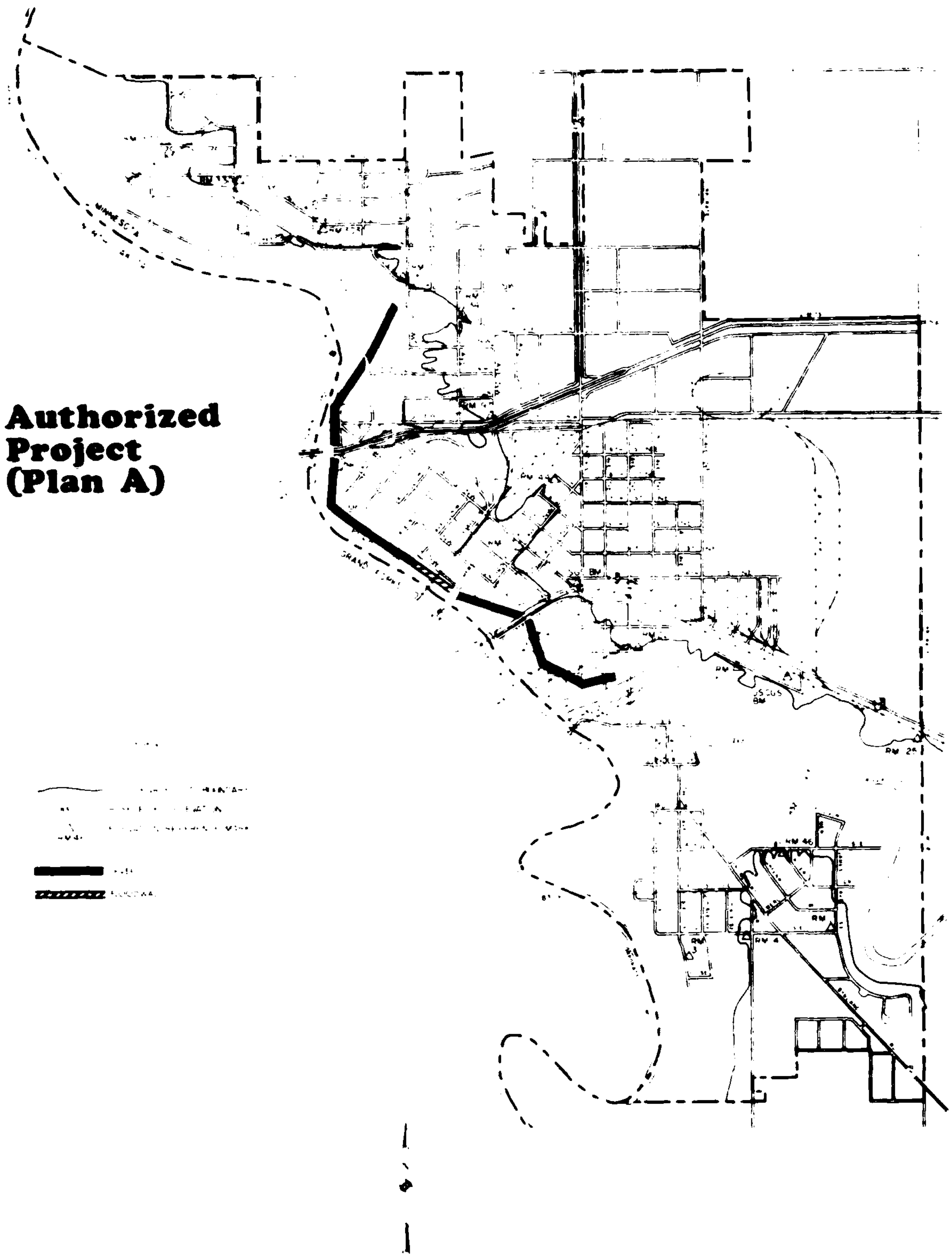

FIGURE 2

East Grand Forks
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Minnesota

Table 1 - Summary of estimated costs

Item	Authorized plan		Modified authorized plan		Modified plan upgraded to 1-percent level of protection	
	3 1/4%	6 5/8%	3 1/4%	6 5/8%	3 1/4%	6 5/8%
Federal first cost	$6,858,000	$6,858,000	$7,809,000	$7,809,000	$8,173,300	$8,173,300
Interest during construction	189,000 (1)	385,400	217,000	417,000	227,200	436,900
Total Federal investment	7,047,000	7,243,400	8,026,000	8,226,000	8,400,500	8,610,200
Non-Federal first cost (2)	479,000	479,000	2,240,000	2,240,000	2,287,700	2,287,700
Interest during construction	15,600	31,700	49,000	100,000	62,900	121,000
Total non-Federal investment	494,600	510,700	2,289,000	2,340,000	2,350,600	2,408,700
Federal annual costs (interest and amortization)	238,800	480,100	271,900	545,900	284,600	571,500
Non-Federal annual costs						
Interest and amortization	16,800	33,900	77,600	155,300	79,600	159,800
Operation, maintenance, and replacement	15,000	16,000	14,000	15,000	14,700	15,700
Total non-Federal annual costs	31,800	49,900	91,600	70,300	94,300	175,500
Total annual costs	270,600	530,000	363,500	16,200	378,900	747,000

(1) No interest charges on engineering and design, supervision and administration.
(2) Excluding engineering and design, supervision and administration costs on lands.

FORMULATION OF MODIFIED AUTHORIZED PLAN

Field observations made during this study indicated that the 6th Avenue NW slide area was still moving and that realignment of the authorized project between 6th and 10th Avenues NW was impractical without the relocation of several garages and near complete loss of all (23) backyards in this area. Replacement of the authorized levee along this reach with a concrete floodwall just riverward of First Street NW appears more practical. Although requiring the purchase by the city of 23 generally well-maintained homes at a total cost of about $1.2 million, this modification would most likely avoid the unstable foundation conditions. Revised total first costs and annual costs for this modified authorized plan (plan B on figure 3) are given in table 1. This plan would not be economically feasible at the 3 1/4-percent interest rate based on present condition benefits (as indicated by the 0.9 benefit-cost ratio shown in table 2). However, benefits attributable to reduction of damages to future growth (reflecting damage reductions accomplished through effective floodplain management and remaining damages to roads and utilities) would result in a benefit-cost ratio of around unity at the 3 1/4-percent rate. This modified plan would not be economically feasible at the 6 5/8-percent interest rate as indicated by a 0.4 benefit-cost ratio (present condition benefits only).

Table 2 - Estimate of benefits

Plan	Total average annual damages (1)	Average annual costs (3 1/4%)	Average annual costs (6 5/8%)	Average annual benefits (2)	Benefit-cost ratio 3 1/4%	Benefit-cost ratio 6 5/8%
Authorized	$656,000	$270,600	$530,000	$316,000	1.2	0.6
Modified-authorized	656,000	363,500	716,200	316,000	0.9	0.4
100-year protection	656,000	378,900	747,000	422,000	1.1	0.6

(1) Floodplain area behind existing city levee system only.
(2) Present conditions only - no benefits attributable to damages to future growth.

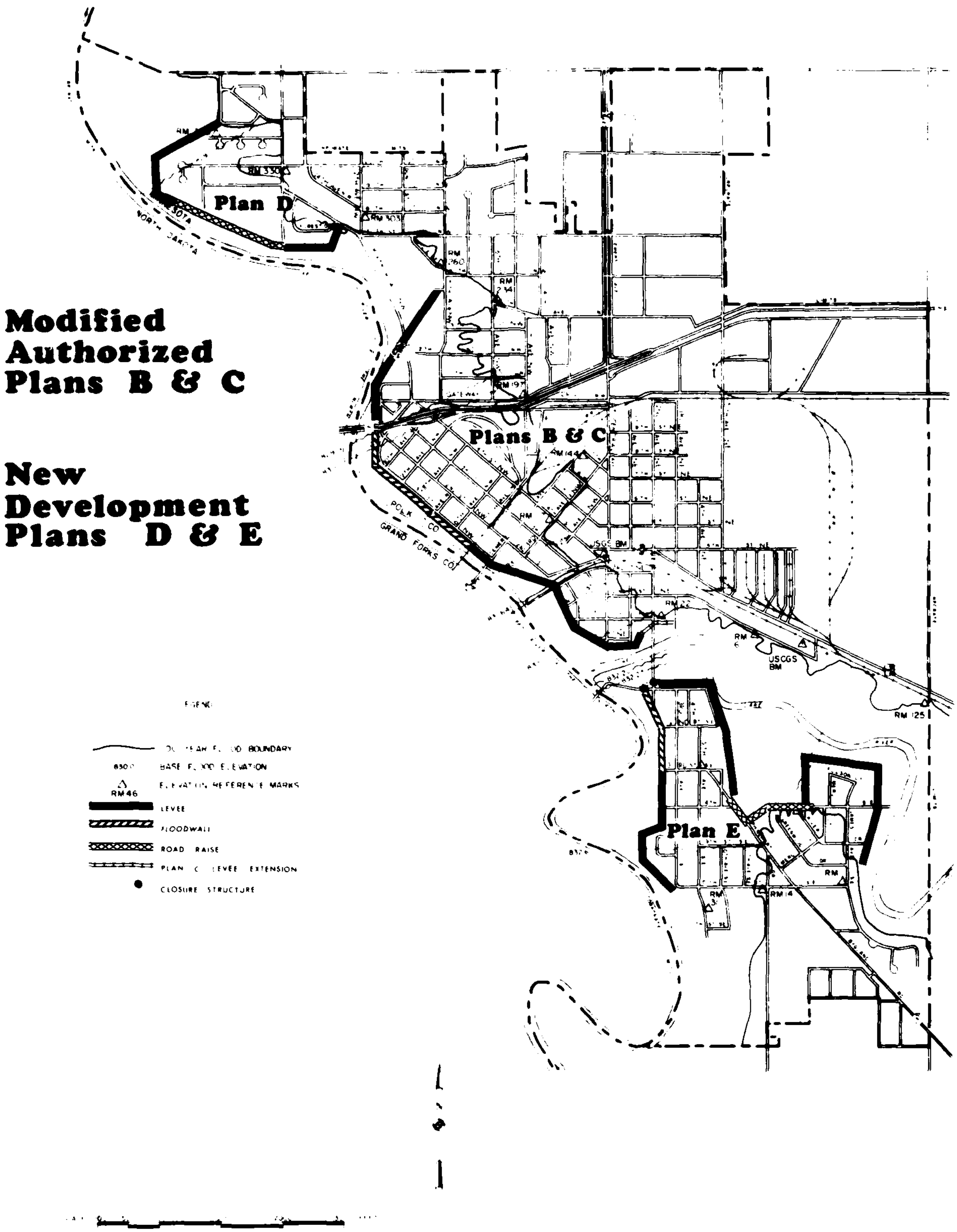

FIGURE 3

East Grand Forks

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Minnesota

UPGRADING MODIFIED AUTHORIZED PLAN TO A 1-PERCENT LEVEL OF PROTECTION

The height of the authorized flood barriers would have to be raised about 1.6 feet and lengthened a total of about 1,200 feet (plan C on figure 3) to protect against a 1-percent chance flood. Minor changes to proposed interior drainage works would be necessary to adjust for a slight increase in contributing drainage area (4.6 acres). Federal and non-Federal first costs to upgrade the authorized project (including substitution of 1,500 feet of floodwall in lieu of levee between 6th and 11th Avenues NW (see figure 3)) are estimated at $8,173,300 and $2,287,700, respectively, as shown in table 1. Also shown are related Federal and non-Federal annual costs of $284,600 and $94,300, respectively, at a 3 1/4-percent interest rate. Average annual benefits of $422,000 (October 1977 price levels and present conditions only) result in a benefit-cost ratio of 1.1 at the 3 1/4-percent interest rate. However, with present condition benefits only and a 6 5/8-percent interest rate, the considered upgrading would not be economically feasible as indicated by a 0.6 benefit-cost ratio.

IMPACTS OF AUTHORIZED PLAN

The authorized plan would require the initial expenditure of $6,858,000 and $479,000 by the Federal Government and local interests, respectively, exclusive of interest during construction. In addition, local interests would bear annual operation, maintenance, and major equipment replacement costs of about $15,000 (based on a 3 1/4-percent interest rate). The modified version of this plan would increase Federal first costs to $7,809,000 and sharply increase local costs to about $2,240,000. However, the modified plan is considered to represent the most technically feasible approach on the basis of adverse local riverbank conditions and current design criteria. Both plans would reduce total flood damages in the central part of the city from $656,000 to about $340,000, a reduction of about 48 percent.

The principal environmental impacts would be the removal of 40 to 50 large trees with associated loss of songbird and squirrel habitat. The flood barriers would be located away from the wooded riverbanks, so little effect on these areas is anticipated. Little change in aesthetic conditions is expected because flood barrier heights would not be changed significantly.

Social well-being impacts would include a marked increase in public health and safety because flooding would be reduced in the developed area. A significant adverse effect with the modified plan would be the removal and relocation of 23 families from the revised alignment. Although expected relocation assistance payments would offset moving costs, the purchase of similar suitable dwellings would be subject to local housing market conditions at that time.

IMPACTS OF UPGRADED 100-YEAR PLAN

This plan would require Federal and non-Federal first costs of $8,173,300 and $2,287,700, respectively. Local operation, maintenance, and replacement costs would be $14,700 annually. Average annual damages within the protected area would be reduced about 64 percent to an estimated $234,000.

Environmental impacts would be essentially the same as for the authorized plan except for the slightly greater aesthetic losses of the 1.6-foot higher flood barrier. Social-well being effects, including sharply reduced incidence of flooding and the adverse relocation impacts, would be nearly the same as with the authorized plan. An additional 53 flood-prone structures would be protected.

OTHER AREAS REQUIRING FLOOD DAMAGE RELIEF

Recent field observations and field flood damage surveys indicate that two developing areas outside the authorized levee/floodwall project need consideration for flood protection. The northern area located between the downstream end of the existing levee system and the north city limits (figure 1) includes about 390 residences and 10 other

(commercial, industrial, etc.) structures within the 100-year floodplain. The southern area located south and east of the confluence of the Red and Red Lake Rivers (figure 1) includes 34 homes and 1 other structure in the 100-year floodplain. Total average annual flood damages for these reaches are estimated at $44,000 and $165,000 (both October 1977 price levels), respectively. Rapid residential development is continuing in the southern area. However, enforcement of local floodplain regulations, recently modified (23 September 1977) in accordance with FIA flood insurance regulations should markedly reduce the flood damage potential to future development.

A very preliminary review of both areas indicates that flood barriers (including levees, road raises, and/or floodwalls together with attendant interior drainage measures, closure structures, and relocation) could reduce flood damages. Considered structural improvements for the northern area (plan D on figure 3) would include 1,800 lineal feet of road raise (with an average height of [illegible] feet) and 2,800 feet of levee (with an average height of 9.5 feet) together with needed interior drainage works to protect against a 1-percent flood. Estimated Federal and non-Federal first costs would be $1,300,000 and $395,000, respectively. A comparison of annual costs of $117,200 (at a 6 5/8-percent interest rate) with related annual benefits (present condition benefits only) of $29,000 indicates an unfavorable benefit-cost ratio of 0.2.

Considered structural measures to protect the southern area against a 1-percent flood (plan E on figure 3) would include 8,000 lineal feet of levee (with an average height of 10.5 feet), 1,400 feet of concrete floodwall (with an average height of 10.4 feet), and three segments of road raise (with an average height of 3.5 feet) totalling 3,100 lineal feet. Also included would be two closures, necessary utility relocations, and interior drainage works. Estimated Federal and non-Federal first costs would be $5,766,000 and $398,000, respectively. Annual costs of $421,800 (at a 6 5/8-percent interest rate) and average annual benefits of $122,000 yield a benefit-cost ratio of 0.3.

From the foregoing analyses based on present condition benefits only, structural flood damage reduction measures do not appear economically feasible for these two areas. Nonstructural measures such as zoning regulations, land use regulations, and other regulatory measures supplemented by emergency relief measures should be considered in postauthorization studies.

SUMMARY AND RECOMMENDATIONS

Existing emergency levees in East Grand Forks do not provide adequate or dependable flood protection. The city remains subject to major economic losses, threats to public health and safety, and possible loss of life. Consideration must be given to upgrading the emergency levees to provide properly designed and constructed flood protection commensurate with local floodplain and flood insurance programs.

The stage 2 studies showed the authorized plan A (67-year level of protection) and the modified authorized plan C (100-year) to be economically feasible at the authorized 3 1/4-percent interest rate. The modified authorized plan C (100-year) is considered to represent the more technically feasible plan on the basis of current design criteria and poor soil stability along the authorized alignment and is recommended for further analysis during postauthorization studies. Flood protection for new development areas north and south of the authorized plan is not economically feasible; further consideration of these areas during postauthorization studies is not recommended. The postauthorization studies might also consider nonstructural measures, such as zoning regulations, land use regulation, and other regulatory measures supplemented by emergency relief measures.

The seriousness of the flood threat to East Grand Forks is unquestioned as are the inadequacies of the existing emergency levee system. Furthermore, the prospects for permanent flood protection as an outcome of postauthorization studies are uncertain. Even if feasibility is shown, several years might pass before studies and plans and specifications are completed, construction is authorized, and funds are appropriated. Therefore, for at

least several years and perhaps the foreseeable future, the city will continue to rely on emergency flood fighting. Therefore, it is recommended that a flood emergency plan of action be developed in stage 3 of the urban study to help the city use its flood fighting resources in the most effective manner and plan for possible flood emergency situations so that the response is quick and effective.

If a permanent levee system is constructed, the plan should be revised accordingly. Extreme flood events from extraordinary combinations of meteorological and antecedent moisture conditions can and have exceeded the design capability of permanent flood barriers in various parts of the country. Therefore, the city should update the plan of action, upgrade the permanent flood protection if needed, and evacuate if the permanent protection fails.

ATTACHMENT A

SUMMARY COST ESTIMATES

Table A-1 - Summary cost estimates of alternatives

Item	Unit	Authorized plan Quant.	Authorized plan Unit cost	Authorized plan Total cost	Modified authorized plan Quant.	Modified authorized plan Unit cost	Modified authorized plan Total cost	Modified plan upgraded to 100-year level of protection Quant.	Modified plan upgraded to 100-year level of protection Unit cost	Modified plan upgraded to 100-year level of protection Total cost	Reach 1 Quant.	Reach 1 Total cost	Reach 2 Quant.	Reach 2 Total cost
Levees														
Embankment	CY	127,000	$0.80	$101,600 (1)	110,400	$3.56	$393,200	133,500	$3.32	$444,100	42,000	$63,000	136,900	
Inspection trench	CY	- (4)	-	-	- (4)	-	-	- (4)	-	-	6,900	22,800	19,700	65,000
Topsoil	CY	12,700	4.00	50,800	11,075	4.00	44,300	11,950	4.00	47,800	4,000	6,000	11,550	17,300
Stripping	CY	6,100	1.20	7,320	4,100	1.20	4,920	5,580	1.20	6,700	4,400	4,800	10,670	11,700
Seeding	Ac	16	700.00	11,200	15.4	700.00	10,780	17.3	700.00	12,100	4.	3,400	15.0	11,300
Clear and grub	Ac	4	1,200.00	4,800	2.7	1,200.00	3,200	2.7	1,200.00	3,200	3.0	4,500	2.0	2,400
Other costs				312,140 (1)										
Contingencies (20%)				97,540			89,600			101,100		26,400		78,000
Total levees				585,400 (1)			546,000			615,000		130,900		391,000
Road raises (2)	LF	0	-	0	0	-	0	0	-	0	1,800	173,100	3,100	204,000
Floodwall (2)	LF	1,500	1,246.20	1,869,300	2,400	1,153.75	769,000	0	-	3,009,000	0	0	1,400	1,700,000
Closure structure (2)	Job	Sum	-	22,200 (2)	Sum	-	22,200	Sum	-	22,000	0	0	2	100,000
Interior drainage (1)	Job	Sum	-	3,340,100 (3)	Sum	-	[illegible],340,000	Sum	-	3,344,000	Sum	800,000	Sum	2,500,000
Relocations											3	150,000	0	
Residences	Ea	0	-	-	23	43,500.00	1,000,000	23	43,500.00	1,000,000	3	150,000	0	0
Relocation assistance	Ea	0	-	-	23	10,400.00	240,000	23	10,400.00	240,000	3	36,000	0	0
Other relocations	Job	Sum	-	20,000	Sum	-	16,000	Sum	-	28,000	Sum	10,000	Sum	80,000
Contingencies (20%)				4,000			249,000			254,000		49,000		20,000
Total relocations				24,000			1,505,000			1,522,000		245,000		100,000
Lands and damages (2)				455,000			410,000			434,000	8.0	106,000	20.0	280,000
Eng. and design, supv. and admin.				1,041,000			1,456,800			1,514,800		240,000		889,000
Total cost				7,337,000			10,049,000			10,461,000		1,695,000		6,16[illegible],000

(1) See attachment B for unlisted cost items.
(2) Includes 25% contingencies.
(3) Includes 20% contingencies.
(4) Included in embankment quantity.

ATTACHMENT B

DETAILED COST ESTIMATE - AUTHORIZED PLAN

ATTACHMENT B

DETAILED COST ESTIMATE - AUTHORIZED PLAN

This estimate represents an update of the May 1966 Interim Survey Report for Flood Control at East Grand Forks. The revised unit costs are based on October 1977 price levels and reflect prices for similar work accomplished recently in this area. The detailed estimate of cost for the authorized local protection works at East Grand Forks is presented in table B-1.

Table B-1 - Detailed cost estimate (October 1977 price levels)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Channels				
Red River of the North and Red Lake River				
Clearing	Ac	30	$1,000.00	$30,000
Contingencies, 20 percent				6,000
Total channels				36,000
Levees and flood walls				
Levees				
Clearing and grubbing	Ac	4	1,200.00	4,800
Removal of existing structures	Job	Sum		37,000
Stripping embankment foundation	CY	6,100	1.20	7,320
Stripping borrow area	CY	35,000	1.00	55,000
Excavation, borrow	CY	149,000	1.40	208,600
Embankment	CY	127,000	.80	101,600
Gravel road surfacing	CY	260	9.00	2,340
Topsoil	CY	12,700	4.00	50,800
Seeding, fertilizing, mulching	Ac	16	700.00	11,200
Relocate and add gate valves to 4-inch water mains under levee	Job	Sum	-	9,200
Contingencies (20%)				97,540
Total levees				585,400

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Levees and flood walls (cont.)				
Flood walls				
Clearing and grubbing	Ac	2	$ 1,200.00	$ 2,400
Removal of existing structures	Job		-	90,000
Excavation, common	CY	5,520	2.50	13,800
Excavation, structure	CY	1,210	6.00	7,260
Backfill, compacted	CY	5,675	6.50	36,890
Filing, steel sheet	SF	3,065	10.00	30,650
Cement	Bbl	8,590	14.00	120,260
Concrete, cantilever wall	CY	5,268	160.00	842,880
Concrete, gravity wall	CY	480	125.00	60,000
Steel reinforcement	Lb	576,000	.45	259,200
Rubber waterstop	LF	4,500	18.00	81,000
Topsoil	CY	1,140	4.00	4,560
Seeding, fertilizing, mulching	Ac	1.4	700.00	840
Relocate 250 lineal feet of 4-inch water mains in area of floodwall, add gate valve and manhole	Job	Sum	-	8,000
Contingencies, (20%)				311,560
Total flood walls				1,869,300
Closure structure				
Aluminum flood barrier at DeMers Ave.	Job	Sum	-	18,500
Contingencies, (20%)				3,700
Total closure structure				22,200
Drainage facilities				
Drainage to Third Street North pumping station				
Stormwater interceptor line "G"				
Catch basin - 1	Job	Sum	-	4,000
27-inch RC pipe (class III)	LF	290	42.00	12,180
Catch basin - 2	Job	Sum		6,000
33-inch RC pipe (class III)	LF	175	60.00	10,500
Manhole A with 21-inch sluice gate	Job	Sum	-	12,000

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Levees and flood walls (cont.)				
Drainage to Third Street North pumping station				
42-inch RC pipe (calss IV)	LF	765	$ 90.00	$ 68,850
Catch basin - 3	Job	Sum	-	6,000
Catch basin - 4	Job	Sum	-	7,500
Catch basin - 5	Job	Sum	-	10,000
Stormwater interceptor line "I"				
54-inch RC pipe (class IV)	LF	400	120.00	48,000
Catch basin - 8	Job	Sum	-	8,000
Manhole - 3	Job	Sum	-	9,600
42-inch RC pipe (class III)	LF	150	80.00	12,000
Catch basin - 7	Job	Sum	-	6,500
33-inch RC pipe (class III)	LF	250	60.00	15,000
Catch basin - 6	Job	Sum	-	5,600
27-inch RC pipe (class II)	LF	200	42.00	8,400
Manhole - 2	Job	Sum	-	3,100
Outfall "J" 21+25				
Manhole	Job	Sum	-	19,000
42-inch sluice gate with hoist	Ea	1	8,200.00	8,200
Gate wall	Job	Sum	-	16,000
84-inch sluice gate with hoist	Ea	1	24,000.00	24,000
84-inch CM pipe	LF	200	145.00	29,000
Diaphragms for 84-inch CMP	Ea	2	2,600.00	5,200
Reed wall	Job	Sum	-	14,000
Sanitary sewer interceptor line "M"				
Manhole - 1	Job	Sum	-	2,400
12-inch RC pipe	LF	120	30.00	3,600
Modify sanitary sewer force main 9+80				
Remove and replace 30-inch force main under levee	LF	280	210.00	58,800
Remove manhole	Job	Sum	-	1,000
Add gate well	Job	Sum	-	3,800
30-inch gate	Job	Sum	-	6,000
Diaphragms for 30-inch pipe	Ea	3	500.00	1,500
Modify snaitary sewer at 11+80				
Remove and replace 18-inch sewer line under levee	LF	275	120.00	33,000
Remove manhole	Job	Sum	-	2,500
Add gate well	Job	Sum	-	6,000
Diaphragms for 18-inch pipe	Ea	3	320.00	960

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Levees and flood walls (cont.)				
Drainage to Third Street North pumping station				
Remove 27-inch RC pipe storm sewer under levee 12+25	LF	100	$ 40.00	$ 4,000
Remove 21-inch RC pipe sanitary sewer under levee 14+05	LF	100	40.00	4,000
Remove 12-inch sanitary sewer under levee 20+25	LF	110	32.00	3,520
Modify storm sewer under levee 26+00				
Remove 48-inch pipe	LF	120	26.00	3,120
Replace with 48-inch CM pipe	LF	120	85.00	10,200
Gate well	Job	Sum	-	6,000
48-inch sluice gate with hoist	Ea	1	12,000.00	12,000
Diaphragms for 48-inch CMP	Ea	3	1,100.00	3,300
Contingencies, (20%)				107,070
Total drainage to Third Street North pumping station				642,000
Drainage to DeMers Avenue pumping station				
Storm water interceptor lines "K" and "L"				
Catch basin - 1	Job	Sum	-	4,400
15-inch RC pipe	LF	95	35.00	3,330
Manhole - 1	Job	Sum	-	7,500
24-inch RC pipe (class IV)	LF	190	76.00	14,440
Catch basin - 2	Job	Sum	-	3,000
30-inch RC pipe (class IV)	LF	240	90.00	21,600
30-inch RC pipe (class IV) jacked under railroad	LF	75	180.00	13,500
Manhole - 2	Job	Sum	-	8,600
Catch basin - 4	Job	Sum	-	7,000
Catch basin - 5	Job	Sum	-	7,800
Stormwater interceptor line "H"				
48-inch RC pipe (class III)	LF	135	92.00	12,400
Catch basin - 6	Job	Sum	-	7,200
42-inch RC pipe (class III) (connect to existing 42-inch CN pipe under DeMers Ave.)	LF	40	80.00	3,200

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Levees and flood walls (cont.)				
Drainage to Demers Avenue Pumping Station (cont.)				
Catch basin - 7	Job	Sum	-	$ 5,600
36-inch RC pipe (class III)	LF	820	$ 70.00	57,400
Catch basin - 8	Job	Sum	-	4,500
Manhole - 3	Job	Sum	-	6,500
Manhole - 4	Job	Sum	-	6,500
Manhole - 5	Job	Sum	-	7,200
Catch basin - 9	Job	Sum	-	4,000
Catch basin - 10	Job	Sum	-	4,200
Manhole - 6	Job	Sum	-	7,200
Outfall "O" 55+30				
Manhole	Job	Sum	-	16,000
36-inch sluice gate with hoist	Ea	1	7,500.00	7,500
Gate wall	Job	Sum	-	16,000
60-inch sluice gate with hoist	Ea	1	16,000.00	16,000
60-inch CM pipe	LF	310	120.00	37,200
Head wall	Job	Sum	-	16,000
Sanitary sewer interceptor lines "T" and "M"				
Manhole - A	Job	Sum	-	6,300
8-inch VC pipe	LF	190	60.00	11,400
Manhole - 8 with gate	Job	Sum	-	9,200
21-inch VC pipe	LF	350	70.00	24,500
21-inch VC pipe in 30-inch sleeve jacked under railroad	LF	75	150.00	11,250
Manhole - C	Job	Sum	-	3,000
Manhole - D	Job	Sum	-	3,000
Manhole - E with gate	Job	Sum	-	10,000
Manhole - F	Job	Sum	-	3,000
Remove 20-inch combined sewer under flood wall 48+65	LF	40	28.00	1,120
Remove 10-inch sanitary sewer under flood wall 50+80	LF	40	35.00	1,400
Remove 8-inch sanitary sewer under flood wall 51+80	LF	40	35.00	1,400
Add manhole - 11	Job	Sum	-	2,000
Modify sanitary sewer force main 52+60				
Remove and replace 16-inch force main under flood wall	LF	40	100.00	4,000

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Levees and flood walls (cont.)				
Drainage to Demers Avenue Pumping Station (cont.)				
Sanitary sewer interceptor lines "T" and "M"				
Add gate well	Job	Sum	-	$ 5,000
16-inch gate	Job	Sum	-	3,600
Remove 12-inch sanitary sewer under flood wall 53+45	LF	40	$ 36.00	1,440
Remove 21-inch sanitary sewer under flood wall 56+50	LF	40	40.00	1,600
Remove 48-inch storm sewer under flood wall 56+80	LF	40	60.00	2,400
Plug 24-inch combined sewer in Demers Avenue 57+20	Job	Sum	-	4,000
Remove storm sewer under levee 64+15	LF	110	40.00	4,400
Contingencies, (20%)				91,620
Total drainage to DeMers Avenue pumping station				549,900
Drainage to Fourth Avenue SE pumping station				
Stormwater interceptor lines "P" and "R"				
Ditch excavation	CY	2,260	3.75	8,480
36-inch RC pipe (class III)	LF	35	60.0	2,100
End section for 36-inch RCP	Ea	1	200.00	200
24-inch RC pipe	LF	20	48.00	960
Manhole	Job	Sum	-	3,600
Outfall Q 86+10				
Manhole	Job	Sum	-	10,000
36-inch sluice gate with hoist	Ea	2	7,500.00	15,000
Gate well	Job	Sum	-	18,000
54-inch sluice gate with hoist	Ea	1	14,000.00	14,000
18-inch sluice gate with hoist	Ea	1	3,800.00	3,800
54-inch CM pipe	LF	310	110.00	34,100
Diaphragms for 54-inch CMP	Ea	2	1,500.00	3,000
Head wall	Job	Sum	-	15,000
Sanitary sewer interceptor lines				
Manhole with 18-inch gate	Job	Sum	-	7,600
18-inch VC pipe	LF	15	40.00	600
18-inch CI pipe (pressure conduit)	LF	100	85.00	8,500

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal first cost				
Levees and flood walls (cont.)				
Drainage to Fourth Avenue SE pumping station (cont.)				
Stormwater interceptor lines "P" and "R"				
Modify sanitary sewer force main				
Remove and replace 12-inch force main under levee 85+70	LF	100	$ 75.00	$ 7,500
Gate well on 12-inch force main	Job	Sum	-	8,500
12-inch gate	Job	Sum	-	3,000
Move 16-inch force main along levee	LF	600	110.00	66,000
Remove and replace 16-inch force main under levee 72+30	LF	150	120.00	18,000
Gate well on 16-inch force main	Job	Sum	-	4,000
16-inch gate	Job	Sum	-	3,400
Remove 18-inch VCP sanitary sewer under levee 86+20	LF	100	20.00	2,000
Remove 24-inch RCP storm sewer under levee 86+30	LF	100	28.00	2,800
Contingencies, (20%)				52,060
Total drainage to Fourth Avenue SE pumping station				312,200
Total drainage facilities				1,504,100
Total levees and flood walls				3,981,000
Pumping plants				
Third Street North pumping station (98,000 gpm)				
Pumphouse including mechanical and electrical equipment	Job	Sum	-	560,000
Discharge piping over levee	Job	Sum	-	30,000
Contingencies, (20%)				118,000
Total Third Street North pumping station (98,000 gpm)				708,000
DeMers Avenue pumping station (38,000 gpm)				
Pumphouse including mechanical and electrical equipment	Job	Sum	-	350,000
Contingencies, 20 percent				70,000
Total DeMers Avenue pumping station (38,000 gpm)				420,000

Table B-1 - Detailed cost estimate (October 1977 price levels) (cont.)

Item	Unit	Quantity	Unit cost	Total estimated cost
Federal First Cost				
Pumping plants (cont.)				
Fourth Avenue SE pumping station (29,000 gpm)				
Pumphouse including mechanical and electrical equipment	Job	Sum	-	$ 330,000
Discahrge piping over levee	Job	Sum	-	30,000
Contingencies, (20%)				72,000
Total Fourth Avenue SE pumping station (29,000 gpm)				432,000
Lift station No. 2 52+10 (sanitary sewer 2,500 gpm)				
Pumphouse including mechanical and electrical equipment	Job	Sum	-	200,000
Remove existing lift station No. 2 from flood wall area	Job	Sum	-	30,000
Contingencies, (20%)				46,000
Total lift station No. 2				276,000
Total pumping plants				1,836,000
Engineering and design				581,000
Supervision and administration				460,000
Total Federal first cost				6,858,000
Non-Federal first cost				
Lands and damages including contingencies and acquisition costs	Job	Sum	-	455,000
Relocations				
Power lines	Job	Sum	-	15,000
Telephone lines	Job	Sum	-	5,000
Contingencies				4,000
Total relocations				24,000
Total non-Federal first cost				479,000
Total Federal and non-Federal first costs				7,337,000

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STAGE 2 FLOODPLAIN MANAGEMENT STUDIES
AT GRAND FORKS, NORTH DAKOTA

RESOURCES AND ECONOMY OF STUDY AREA

LOCATION AND EXTENT

The city of Grand Forks, North Dakota, is located along the left bank of the Red River of the North at the confluence with the Red Lake River (Red River mile 298.0). The contributing Red River of the North drainage area at the USGS (U.S. Geological Survey) stream gage (mile 295.7) is 30,100 square miles including the 5,700-square mile Red Lake River sub-basin in Minnesota. At Grand Forks, the Red River is about 200 feet wide and 8 to 10 feet deep during normal summer flows. The river is situated on the flat bed of former glacial Lake Agassiz; topographic relief changes are small as indicated by an average channel bottom slope at Grand Forks of about 0.5 foot per mile.

The Grand Forks study area for flood control includes the immediate Red River of the North floodplain including the English Coulee floodplain between the south and north city limits. To aid in the analyses of flood damage reduction needs, the study area was separated into six separate reaches as listed below and shown on figure 1.

Reach 1 - South city limits to Almonte Avenue. This reach includes Grand Forks' Belmont Coulee and Belmont Road areas from the southern city limits to near the upstream end of the existing Lincoln Park levee/floodwall project.

Reach 2 - Almonte Avenue to Seventh Avenue South extended. This reach covers the existing Lincoln Park levee/floodwall project.

Reach 3 - Seventh Avenue South extended to Minnesota Avenue. This reach includes the Central Park neighborhood and existing emergency levee. The downstream limit coincides with the confluence of the Red and Red Lake Rivers.

Reach 4 - Minnesota Avenue to Seventh Avenue North. This reach includes the downtown business district.

Reach 5 - Seventh Avenue North to Coulee Drive. This reach includes the Riverside Park neighborhood and existing emergency levee.

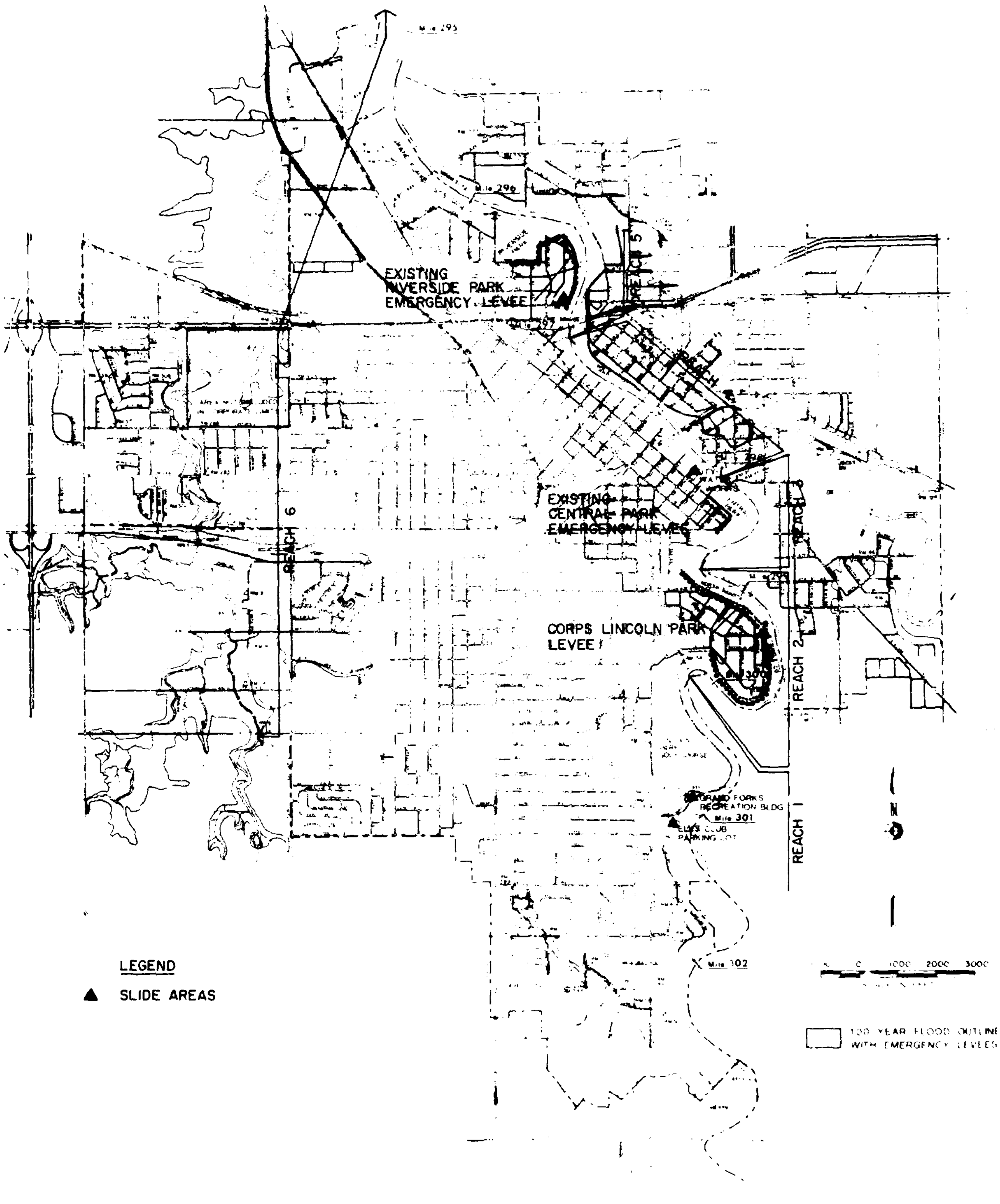
Reach 6 - English Coulee floodplain from mouth to 17th Avenue South. This reach covers the coulee to the approximate upstream limits of the 100-year flood outline defined by the Flood Insurance Administration's 30 September 1977 Flood Boundary and Floodway Map.

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

The Grand Forks study area is located along the fringe of the Northern Floodplain Forest and treeless prairie ecosystems. Typical overstory in the floodplain forest includes basswood, American elm, green ash, bur oak, hackberry, cottonwood, and box elder. Buckbush, hawthorne, gooseberry, hop hornbeam, and prickly ash typify the understory. Waterleaf, wood nettle, bedstraw, and columbine are the most common ground cover. Much of the bottomland area subject to periodic flooding is maintained as park or open space. Strips of woodland immediately adjacent to the river remain relatively undisturbed mainly because of their high flood potential. Little if any original prairie grasses exist on the upland areas as a result of continued urbanization. Exotic tree, shrub, and ground cover species have replaced the original tall and medium prairie grass species.

Common small mammals in the forested floodplain include the red squirrel, Franklin ground squirrel, woodchuck, deer mouse, eastern meadow mouse, cottontail rabbit, and snowshoe hare. Raccoon and striped skunk are also abundant. Several species of mice, moles, chipmunks, squirrels, and rabbits are the most common mammals found in the urbanized residential areas. Because turbidity is high, only the very "hardy" species of fish such as minnows and carp are found in the Red River of the North study reach.

Both the floodplain forest and urban residential areas support a variety of birds. Owls, woodpeckers, and numerous songbirds (over



EXISTING FLOOD CONTROL IMPROVEMENTS

FIGURE 1

20 species) are found in the wooded floodplain. Sparrows, robins, mourning doves, thrashers, and warblers frequent wooded urbanized areas. Pigeons are a common nuisance in the commercial-industrial areas. Few if any threatened or endangered fauna are considered to inhabit the study area. Possibly found in the study area on an occasional basis are the fisher (status undetermined), pileated woodpecker (special interest), mud puppy (one recorded observation in Red River at Grand Forks - special interest), and the gray tree frog (special interest). Few if any threatened or endangered flora are considered to exist in the riverbank and urbanized areas since these areas have long ago been reworked and regenerated with weeds or exotic grass species.

HUMAN RESOURCES

The city of Grand Forks has grown in population from 34,451 in 1960 to 41,601 in 1973. Population in the study area is evenly dispersed in all reaches except in the downtown business district portion of Reach 4. The most rapid population expansion is occurring in Reach 1, the Belmont Road area in south Grand Forks. Highest population densities are found in the extremities of Reach 4 (the downtown area) and Reach 2 (the Lincoln Park area). In terms of occupational distribution, Reach 1 has a substantially higher percentage of professionals than all other reaches. And, as expected, this same area has the greatest percentage of employed persons with annual incomes over $15,000. Reach 1 has also the largest percentage of population 25 years and older with 4 or more years of post-high school education.

DEVELOPMENT AND ECONOMY

The Grand Forks study area includes the "hub" of the local economy. Much of the downtown retail, financial, and commercial business district (Reach 4) is within the 100-year floodplain. A relatively minor amount of industrial development is in the downstream portion of Reach 5. The highly developed area (Reach 4) is served by an extensive network of roads

and railroads. U.S. Highway 2, Demers Avenue, and Minnesota Avenue provide easy access to East Grand Forks and eastern areas. U.S. Highway 81 provides "gateways" to northern and southern areas. Railroad passenger and freight services are provided by the Burlington Northern Railroad with two river crossings in the study area. A local "ring road" along the riverbank between Kittson Avenue and First Avenue North enhances local traffic and provides parking for downtown commuters.

The growth and strength of the local Grand Forks economy are well illustrated by an over fourfold increase in taxable sales and a threefold increase in building permit valuations between 1950 and 1975. Similarly, wholesale and retail trade in the city increased by 112 and 139 percent, respectively, between 1963 and 1972.

PROBLEMS AND NEEDS[1]

EXISTING FLOOD CONTROL PROJECTS

The existing Corps flood control project (in Reach 2) at Grand Forks was completed in 1958 and consists of a 5,160-foot earthen levee with an average top height of 14 feet, a 770-foot reinforced concrete floodwall, and interior drainage works including a 21,720-gpm (gallon-per-minute) capacity pumping station as shown on figure 1. Also included were utility and road relocations, lands, easements, and rights-of-way furnished by the city as local cooperation items. The earth levee has a 10-foot top width and 2.5 horizontal to 1.0 vertical side slopes. The project was designed to protect the Lincoln Park area from a 79,000-cfs (cubic-foot-per-second) or 50-year Red River flow with 2 feet of freeboard. The 79,000-cfs flow was the maximum flood of record at the time the project was constructed. On the basis of current hydrologic data, the top of the flood barrier is approximately at the 49.8-foot stage or 1.2-percent chance flood flow height as measured at the USGS gage at river mile 295.7 (gage zero = 778.35, 1929 adj.)[2] About 200 residences and various commercial and industrial structures and public buildings are protected from a 2.8-percent chance (36-year) flood flow by the project.

A small flood control project has recently been studied by the North Dakota State Water Commission for Belmont Coulee at Belmont Road. Improvements, consisting of a proposed combined roadway-embankment, gated conduits, and interior drainage pumping facilities, were designed to prevent periodic flooding of the mostly residential Belmont Coulee area. However, the project has not been constructed because local acceptance is lacking.

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(1) The stage-discharge, frequency-discharge, and historic flood data cited in this stage 2 report were revised later in the urban study. Differences between these and later data reflect Corps efforts to refine the hydrologic and hydraulic data base. Also, the existing flood barriers have been improved during and following flood fights which occurred after this report was printed. However, the stage 2 data have been reprinted here to allow the reader to follow the original decision-making process.

(2) Current gage zero = 778.35 (1929 adj.) at mile 295.7. Gage zero was 778.35 at mile 296.0 prior to relocation of gage in 1965. Gage zero was 778.42 at mile 296.22 prior to gage relocation in 1933.

EMERGENCY LEVEE WORKS

Emergency levee works constructed by the Corps of Engineers during past flood emergencies remain at two locations in Grand Forks. The Central Park levee (figure 1) was constructed during the 1971 flood emergency. This levee is 1,500 feet long with an average 10-foot top width and 3 horizontal on 1 vertical side slopes and had a maximum height of 7 feet. The 7-foot maximum height corresponds to a stage of 46.8 feet (elevation 825.2 as measured at the USGS gage at mile 295.7). This levee was raised during the 1978 flood emergency to a stage of 50.0 feet. Any required interior drainage pumping would be provided by temporary portable pumps during a flood emergency. Extremely long sandbag closures or other methods of closure are required to make this levee effective. Assuming no levee failure along with effective closures and interior drainage pumping, about 50 residences and other structures would be protected at the 50-foot flood stage (3.3-percent chance flood level with 3 feet of freeboard).

The other emergency flood barrier is in the northeast part of the city between U.S. Highway 2 on the south and Riverside Park on the north as shown on figure 1. This barrier was constructed in 1975 and consists of a 3,450-foot earthen levee and wood plank wall. The 2,800-foot levee portion has a 10-foot top width, an average height of 8 feet (47-foot stage, 3.3-percent chance flood), and side slopes varying from 2:1 to 3:1 on the riverward side and 3:1 to 4:1 on the landward side. A 650-foot wood plank wall supported by 8- by 8-inch beams on 6-foot centers constitutes the remainder of the flood barrier. No permanent interior drainage facilities are provided. Seepage and interior surface runoff would be removed by temporary portable pumps during an emergency. Approximately 50 residences and other structures are protected by the levee.

FLOOD EMERGENCY AND NONSTRUCTURAL EMERGENCY PROGRAMS

Responses to impending flood emergencies at Grand Forks are accomplished by the City Department of Public Works. The level and nature of the response is based on predictions of impending flood crests provided by the National Weather Service in Fargo, North Dakota. For smaller floods not expected to overtop the existing levees, typical activities would include monitoring the operation of the existing Lincoln Park levee/floodwall project, placing a sandbag closure at the Central Park levee, installing stop log closures in the Riverside Park levee, and providing emergency interior runoff and seepage pumping behind both emergency levees and sandbagging of the city waterworks and NSP powerplant.

During a major flood, government agencies (such as the Corps of Engineers) may be asked to provide technical, manpower, and financial assistance in raising or constructing needed temporary flood barriers. Other agencies (such as the National Guard, U.S. Coast Guard, Salvation Army, and the Red Cross) typically provide emergency relief assistance such as evacuation of threatened residents, shelter, and patrol of flood barriers.

Current administrative techniques being used to reduce potential flood loss include enrollment in the regular phase of the National Flood Insurance Program and the recent adoption of floodplain zoning and subdivision regulations to regulate development in flood-prone areas. The development of the three community parks - Lincoln, Central, and Riverside - has effectively precluded high-density damage-prone development which otherwise might have occurred in these areas.

EXISTING FLOOD PROBLEM

The city of Grand Forks is subject to periodic flooding from the Red River of the North. Principal factors contributing to flooding include the very flat river slope, northward drainage, channel constrictions, and

and increasing agricultural drainage. The low river slope of 0.5 foot per mile and resultant low velocities retard drainage from the area. The flow of surface runoff from southern areas into still frozen river reaches frequently results in ice jams and increased river stages. Bridges over the river, particularly the Burlington Northern Railroad and Demers Avenue Bridges, obstruct flood flows at higher stages.

The city of Grand Forks is subject to spring floods caused mainly by snowmelt runoff and summer floods resulting from heavy rains. An exception, the 1965 flood, was caused principally by heavy widespread rainfall over deeply frozen soils. A list of the 10 largest floods of record at Grand Forks together with corresponding flood crest heights and discharges is given in table 1.

Table 1 - Ten highest floods in order of magnitude, Red River of the North at Grand Forks, North Dakota(1)

Order No.	Date of Crest	Gage height: Stage (feet)	Gage height: Elevation (feet)(2)	Estimated peak discharge (cfs)
1	10 April 1897	48.5	826.8	79,000
2	18 April 1882	46.3	824.6	68,000
3	4 April 1966	45.55	823.90	55,000
4	11 April 1978	45.73	824.08	54,200
5	12 May 1950	45.5	823.8	54,000
6	16 April 1969	45.69	824.04	53,500
7	24 April 1893	43.8	822.2	53,300
8	17 April 1965	44.92	823.27	52,000
9	14 July 1975	43.27	821.62	45,000
10	25 April 1950	43.8	822.2	43,800

(1) Does not show the 1979 spring flood (48.81, 827.16, 82,000) which occurred after this stage 2 report was completed. Nor have some data, notably the 1897 flood, been updated. Revised tables are shown in the Plan Formulation Appendix and Flood Emergency Plan for Grand Forks, North Dakota.

(2) Gage zero = 778.35 (1929 adj.)

Flooding begins at a Red River stage of about 28 feet (elevation 806.35); appreciable flood damage begins at a stage of 35 feet. Major flood damages begin at a stage of about 40 feet with seepage into

basements in the downtown business district. At a 47-foot stage, the Grand Forks water treatment plant is inoperative requiring emergency supplies from East Grand Forks. At a 49-foot stage, the Northern States Power plant is shut down. The maximum flood of record occurred in 1897 with a stage of 48.5 feet, a peak discharge of 79,000 cfs, and a corresponding expected return interval of once in about 62 years. The 1-percent chance flood would have a maximum stage height of 50.4 feet and a corresponding discharge of 89,000 cfs.

A large part of the urbanized area (see figure 4, 1-percent chance flood outline) is subject to either direct (surface water) or indirect (sewer backup, etc.) flooding. Flood damage figures include actual damages to residential, commercial, industrial, and public structures plus flood fight and cleanup costs. Over 2,600 residential, commercial, and public buildings would be subject to direct flooding from the 1-percent chance flood. Major disasters were averted in Grand Forks during the 1965, 1966, 1969, and 1978 spring floods through flood fight measures, including construction of emergency flood barriers at Central and Riverside Parks. Without these measures, flood damages would have been about $400,000 in 1965 and nearly $1 million in 1966 and 1969 (all October 1977 prices). The 1975 summer flood (8-percent frequency flood) resulted in $496,000 in damages (October 1977 price levels) including direct property damage, flood fight costs, and cleanup of sewers and surface debris. Under present conditions and prices and assuming no emergency flood fight, a recurrence of the record 1897 flood would result in damages of about $18 million. An occurrence of the 1-percent chance flood would result in total damages of about $47 million. A summary of historic flood damages for selected floods at Grand Forks is given in table 2.

Table 2 - Summary of historic flood damages

Year	Peak flood stage (feet)	Total flood damages	Damages prevented (1)
1965	44.92	$306,000	0
1966	45.55	518,000	$445,000
1969	45.69	420,000	897,000
1975	43.27	496,000	396,000

(1) Damages prevented by flood fight efforts, emergency levees, and Corps Lincoln Park levee (October 1977 price levels).

The completed Lincoln Park levee project protects that area from a 2.8-percent chance flood (36-year) with 3 feet of freeboard. An occurrence of the 1-percent chance flood (approximate stage of 54.3 at midpoint of levee) would overtop the levee by about 0.6 foot.

The Central Park area (see figure 1) is protected to a limited and uncertain degree from a 3.3-percent frequency flood (stage of 50 feet, discharge 63,000 cfs), offering residents a false sense of security against flooding. This levee was constructed quickly during a flood emergency without due regard for Corps design criteria including accepted minimum levels of protection in densely urbanized areas. In the event of a major flood, this levee is susceptible to erosion and/or overtopping and needs a lengthy closure at Minnesota Avenue.

Similarly, the existing Riverside Park levee and floodwall protects about 50 residences from a 3.3-percent chance flood assuming no failure of the levee and adequate interior drainage pumping. However, the 100-year (1-percent chance flood) flood would overtop the flood barrier by 0.7 foot; flood damages in the area would be about $2,500,000. Thus, this flood barrier also creates a false sense of security against flooding and leaves the area subject to potentially high economic losses.

The highly developed downtown business district begins suffering basement seepage damage with the 17.5-percent chance or 5.7-year flood Approximately 70 square blocks of the downtown area between Minnesota Avenue and U.S. Highway 2 would be inundated by the 1-percent chance flood.

Substantial flood damages are frequently incurred at the three city parks located adjacent to the river. Since 1966, these parks have been inundated 10 times. Recurring flood losses at these parks include damage to structures, cleanup of debris and mud from the grounds, and loss of revenue at the Lincoln Park golf course. For the two occurrences in 1975, over $200,000 in Federal and local disaster relief funds were expended for repairs and clean up at the parks. Approximately $30,000 in golf course receipts were lost at Grand Forks because of the 1975 summer flood.

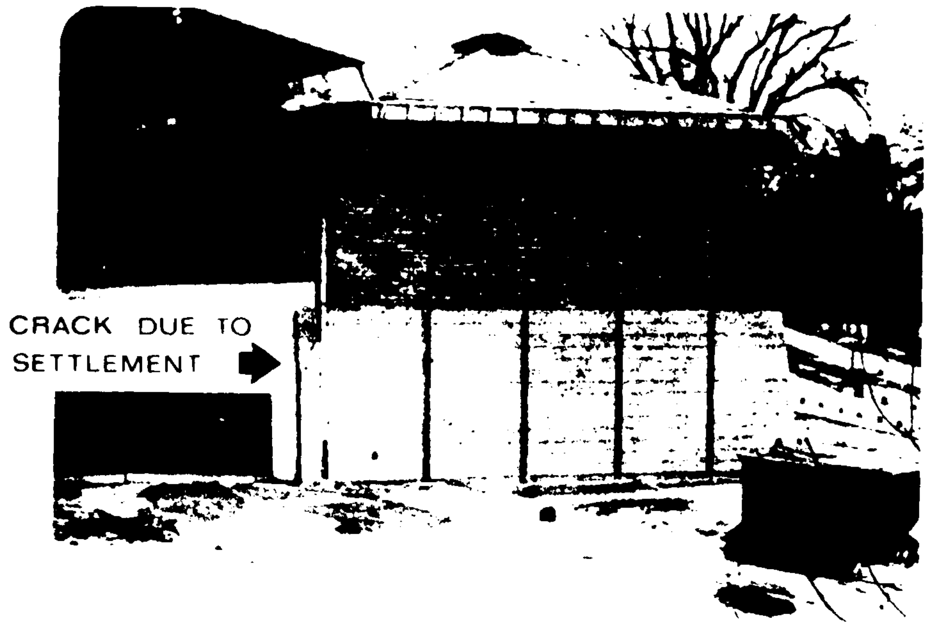
RIVERBANK STABILITY PROBLEMS

In addition to being of inadequate height and questionable structural integrity, the existing emergency levees are also located on or near unstable riverbank areas. A weak layer of lacustrine deposits deposited during the glacial Lake Agassiz period is present at a depth of roughly 50 feet throughout the area. This layer is about 30 feet thick in areas undisturbed by subsequent river erosion. In some areas, this layer has been completely replaced with more stable fluvial deposits. There is substantial evidence that levees and other structures constructed in areas of undisturbed weak lacustrine deposits have resulted in severe riverbank slides and resultant damage to flood barriers and other structures.

Several slide areas have been observed along the Grand Forks side of the Red River; most of them are active or are undergoing slow but continual movement (figure 1). An active slide is located under the upstream end of the Riverside Park levee. This slide started in 1972. Addition of more emergency levee fill in 1976 increased the rate of movement with subsequent subsidence of the levee and cracking of nearby building foundations. Another slide occurred in 1946 at the city waterworks because of placement of added fill landward of the water storage tank. However, this area currently appears stable.

Another slide occurred in 1953 at the upstream end of the existing Corps project in Lincoln Park requiring unloading of the riverba , relocation of nearby homes, and replacement of 400 feet of levee with floodwall. Other than a separated vertical joint in the floodwall, which probably occurred shortly after construction, visual evidence shows this slide area to be inactive.

A continuing slide exists at the Grand Forks recreational building (see photo). The building has been severely cracked and the lower floor is unusable.



Grand Forks Recreational Building

Another slide area is located farther upstream at the Elks Club parking lot. This slide area appears active with observed vertical displacement in the paved parking lot of over 2 feet.

IMPROVEMENTS DESIRED

Even with the existing Corps project, emergency levees, periodic emergency flood fight activities, and current nonstructural measures, Grand Forks is subject to severe flood damage from a major flood occurrence. Although relatively effective in the past, the emergency levees are inadequate in height and design and are undergoing foundation failure in some areas. Thus, these levees offer affected residents a false sense of security and leave them with a real threat to life and property. Thus, a comprehensive program including nonstructural and structural measures appears advisable to provide adequate protection for a heavily urbanized area. At an 18 January 1978 workshop meeting in Grand Forks, the city expressed a desire that consideration be given to flood damage reduction measures at Lincoln Park and that riverfront beautification measures be incorporated as part of any

proposed flood barrier work. The city also desires the formulation of an emergency plan of action to more effectively cope with flood emergencies in the absence of any permanent flood damage reduction measures. The city has indicated its interest in area flood protection by requesting that such needs be given high priority in the ongoing Corps of Engineers Grand Forks-East Grand Forks Urban Water Resources Study.

PLAN FORMULATION

The purpose of plan formulation was to develop the optimum plan for flood damage reduction at Grand Forks. The process involved the identification and development of alternative measures, identification of impacts, and evaluation of the alternatives considered based on screening and trade-offs of impacts.

PLANNING OBJECTIVES

Two overriding planning objectives were used to guide the formulation process: National Economic Development (NED) and Environmental Quality (EQ). Specific local planning objectives developed on the basis of area problems and needs, concerns of local interests, and flood damage reduction opportunities included the following:

- Contribute to the protection from and/or reduction of flood losses to relieve the economic and psychological burdens on society and local residents in Grand Forks' flood-prone areas during the 1980-2030 planning period.

- Contribute to the preservation and enhancement of the environmental quality of Grand Forks' floodplain areas to increase wildlife and recreational values during the 1980-2030 planning period.

- Contribute to the social well-being of Grand Forks area residents to enhance the quality of life during the 1980-2030 planning period.

- Contribute to the protection of floodplain lands to discourage unwise development that would be flood-prone or would detract from the environmental quality during the 1980-2030 planning period.

FORMULATION AND EVALUATION CRITERIA

For the analysis and comparison of alternatives with the base or existing condition, various criteria were established. The base condition is identified as the Grand Forks area having floodplain management ordinances and flood insurance in effect but remaining subject to recurrent flooding with very serious damage potential.

Specific criteria considered included economic, technical, environmental, and social well-being criteria as briefly outlined below.

Economic Criteria

- Tangible economic benefits of a selected plan must exceed costs (i.e., a benefit-cost ratio greater than unity).
- A 100-year amortization schedule is used as a basis of economic analysis.
- Annual costs and benefits are based on a 6 5/8-percent interest rate and October 1977 price levels and conditions.
- Any plan developed should fit integrally into an overall plan for flood damage reduction in the Red River basin.

Technical Criteria

- Where feasible, nonstructural measures are preferred over structural measures.
- All flood barriers and channels will provide 3 and 2 feet of freeboard, respectively, over the design water surface elevation.
- Where feasible, the flood barrier freeboard should contain the standard project flood flow or the maximum practical level of protection.

- Unstable riverbank slopes will not be loaded in excess of acceptable design limits.
- Appropriate Corps engineering standards, regulations, and guidelines will be complied with.

Environmental Criterion

- A plan that minimizes adverse environmental effects and maximizes environmentally related benefits before, during, and after construction will be developed and selected.

Social Well-Being Criteria

- The possible loss of life and threats to area public health and safety will be minimized.
- Social, cultural, historical, and aesthetic values in the study area will be preserved and, where possible, enhanced.
- The selected plan must be responsive to the desires of the community and acceptable to the people.

BASE CONDITION

The existing or base condition for the flood damage reduction analyses in the city of Grand Forks is as follows: The Lincoln Park area has a 36-year level of protection provided by the existing Federal project. The Riverside Park area has a questionable degree of protection up to the 33-year flood level provided by the locally built emergency flood barrier. Similarly, the Central Park area is provided questionable protection up to the 50-foot flood stage (33-year flood level with 3 feet of freeboard) by the emergency levee. Other current measures used to reduce potential flood damages include flood warning services provided by the National Weather Service, flood fight and disaster relief activities by the city and other government agencies, flood insurance, and recently adopted floodplain zoning and subdivision regulations to regulate development in flood-prone areas.

With these structural and nonstructural measures, the developed floodplain areas of the city remain subject to inundation with a related high potential for economic losses and threats to public health and safety. Previous instances of levee subsidence along the Riverside Park levee make questionable the advisability of this and other hastily built barriers. Other areas such as Reach 1 (Belmont Road area) and Reach 6 (English Coulee) are not protected except by private flood fight efforts such as sandbagging of individual properties.

Under present conditions, total flood damages for all reaches for the 50-year, 100-year, and standard project flood levels would exceed $13 million, $42 million, and $76 million, respectively, on the basis of October 1977 price levels and conditions as shown on table 3. Corresponding average annual damages exceed $1 million.

Table 3 - Summary of total flood damages

Reach	50-year flood level	100-year flood level	Standard project flood level
1	$1,300,000	$2,380,000	$3,950,000
2	3,560,000	5,800,000	9,600,000
3	1,730,000	3,050,000	7,100,000
4	3,200,000	24,000,000	45,000,000
5	1,660,000	2,540,000	4,500,000
6	2,000,000	4,970,000	6,400,000
Total	13,450,000	42,740,000	76,550,000

ALTERNATIVE PLANS CONSIDERED

Measures considered to either wholly or partially meet the flood damage reduction needs of the city of Grand Forks were classified as nonstructural or structural. Structural measures (e.g., levees, dams, channel improvements, etc.) affect the floodwaters; nonstructural measures (e.g. floodplain

regulations, flood proofing, relocations, etc.) reduce the flood damage potential. Some nonstructural measures, such as flood proofing, include construction work but not to the scale of structural measures such as levees. In addition to the no action alternative, six nonstructural and four structural plans were considered. Costs and major social and environmental impacts of these alternatives are on table 4.

NONSTRUCTURAL MEASURES

No Action

This alternative would include only those measures currently utilized under the existing base condition. Flood damage reduction would be limited to that obtained with the existing flood barriers together with necessary closures, prior flood warnings from the National Weather Service, emergency diaster relief activities such as temporary evacuation and housing of relocated people, and private flood proofing efforts. Persons who purchased flood insurance would be at least partially reimbursed for flood losses in accordance with the terms of their coverage.

When severe flood conditions are forecast, it is likely that technical assistance at least would be sought from various local, State, and Federal agencies. Typically, the Red Cross would assist in housing of evacuees and the Corps of Engineers would provide technical assistance regarding emergency flood barrier construction.

Flood Warning and Forecasting Services

The National Weather Service provides rainfall and snowmelt advisory flood forecasts for the Red River and its major tributaries. It predicts a given stage at a particular gage or gages in the basin on the basis of observed precipitation and flow at upstream points as well as anticipated weather conditions. The forecast is transmitted to local officials, newspapers, and radio and television stations in the basin. These sources

disseminate the information to residents of the floodplain in the form of a flood warning. Even though the anticipated flood may be of moderate proportions, forewarning permits industrial plants, public utilities, municipal officials, and individuals with property in the lowlands to take protective measures.

Forecasting covers both flash floods and major flood forecasts. Flash flood warnings are issued by the Fargo office if flood-producing rainfall is reported or if there is at least 80-percent chance that flash flooding will occur. Time limits for these flash floods would probably not permit construction of emergency works, but may permit some evauation of personnel and movable property. Flash flooding is not a major problem at Grand Forks. Major floods on the Red River usually occur in the early spring as a result of rapid melting of heavy snow cover combined with warm rains during the melt. For snowmelt advisory forecasts, the lead-time between distribution of this information and the flood crest may range from 1 to 4 weeks. Emergency flood protection barriers have been constructed during major flood periods in the past in response to forecasts and are depicted on figure 4.

Flood Insurance

The flood insurance program established by the National Flood Insurance Act of 1968 makes available specified amounts of flood insurance previously unavailable from private insurers. The act requires that local governments adopt and enforce land use controls and other regulatory measures that will guide development in flood-prone areas to avoid or reduce future flood damages.

The 1973 Flood Insurance Act requires that all buildings in the special flood hazard areas (100-year floodplain) of a participating community must be covered by flood insurance to be eligible for any form of assistance or guarantees from a federally-insured or-supervised bank or savings and loan association or from any Federal agency. An

Table 4 - Comparison of alternatives considered[1]

Impact Category	Non-Structural: Flood Warning & Forecasting Services	Flood Insurance	Flood Plain Regulation Practices	Permanent Evacuation and Relocation	Flood Proofing	Emergency Flood Fight Activities	Structural: Flood Barriers[2]	Floodwater Diversion	Reservoir Storage	Channel Modifications
ECONOMIC										
Federal First Cost	Not Estimated[3]	$ 0	$ 0	$ 69,100,000	$ 36,400,000	$ 3,000,000	$12,609,000	$ 90,000,000	Not estimated	Not Estimated
Non-Federal First Cost	Not Estimated	2,000,000	150,000	17,300,000	9,100,000	800,000	3,547,000	2,500,000	Not estimated	Not Estimated
Federal Annual Costs	Not Estimated	0	0	4,771,000	2,513,000	199,000	837,000	5,970,000	Not estimated	Not Estimated
Non-Federal Annual Costs	Not Estimated	193,000	50,000	1,194,000	630,000	53,000	275,000	200,000	Not estimated	Not Estimated
Total Annual Costs	Not Estimated	193,000	50,000	5,965,000	3,143,000	252,000	1,112,000	6,170,000	Not estimated	Not Estimated
Total Annual Benefits[4]	$107,300	-	-	1,009,000	966,000	305,000[6]	415,000	1,402,000[7]	$ 230,000	-
Benefit-Cost Ratio[4]	N/A	-		-[5]	0.31	1.2	0.37	.23	-	-
Remaining Flood Damages	967,000	1,074,000	1,074,000	64,000	108,000	69,000	551,000	327,700[8]	844,000	-
Percent Flood Damage Reduction[3]	10	0	0	94	90	28	39	81	21	-
Employment	No Effect	No Effect	No Effect	Temp. increase in area employment as a result of hired labor for evacuation efforts.	No significant change over present.	Very short term increases in hired labor.	Temporary two-year increase in employment resulting from locally hired labor for project construction. Permanent one man-year increase for operation and maintenance of [illegible]	Temporary 3-yr increase resulting from locally hired unemployed labor.	No effect in project area.	Same as Flood Barrier Plan.
Tax Values	No Effect	No Effect	No Effect	Temporary 2-3 year major loss during relocation period. Long term gain in tax receipts from new development on flood-free property.	Probable slight increase in property taxes with increased valuation for flood damage free homes.	No Effect	Probable major increase in property taxes from flood-free property.	Same	Probable minor increase.	Probable minor increase.
Property Values	No Effect	No Effect	No Effect	Major short-term loss. Long-term increase.	Slight increase for flood proofed homes.	No significant effect.	Major increase in new flood-free areas.	Same	Probable minor increase.	Probable moderate increase with increased flood-free property.
Public Facilities	Continued damage to park grounds and facilities as a result of flooding.	Same	Same	Same	Continued damage to facilities in three major City parks.	No significant effect as present park facilities cannot practically be protected.	Long-term protection for facilities in protected areas. No effect on existing riverside park facilitie unless alternative Lincoln Park barrier was constructed.	[illegible] flood losses at three city parks [illegible] river	Moderate reduction in flood damage at 3 major parks.	Temporary adverse effect from required bridge raising. Permanent loss of some park lands for flood control channel.

Table 4 - Comparison of alternatives considered[1] (cont)

Impact Category	Non-Structural: Flood Warning & Forecasting Services	Flood Insurance	Flood Plain Regulation Practices	Permanent Evacuation and Relocation	Flood Proofing	Structural: Emergency Flood Fight Activities	Flood Barriers[2/]	Floodwater Diversion	Reservoir Storage	Channel Modifications
ECONOMIC Continued:										
Public Services	Continued loss of use of parks and golf course facilities during and for at least a one-month period after flooding.	Same	Same	Same	No significant effect as low-lying park facilities cannot feasibly be flood-proofed with continued periodic loss of use	Disruption of regular public services due to diversion of local manpower and financial resources during flood fights.	Long-term freedom from disruption in protected areas. No change at unprotected park areas.	Continued periodic loss of use at 3 major City parks. Greatly reduced flood fight requirements.	Moderately reduced flood fight requirements. Increased use of park areas.	No significant beneficial effect.
Income	No Effect	No Effect	No Effect	Major loss of area income for several years with relocation of downtown business district.	No significant effect.	Very slight increase i.e. flood fight labor.	Temporary increase due to hiring of locally unemployed manpower resources.	Same as Flood Barrier Plan.	Same as Flood Barrier Plan.	Same as Flood Barrier Plan.
Regional Growth Activity	No Effect	No Effect	Restricted growth in 100-year flood plain.	Major dislocation during several-year relocation and rebuilding period.	No Effect.	No Effect.	No major effect.	Significant changes to current urban growth patterns west and south of Grand Forks.	No effect in project area.	No Effect.
Business and Industrial Activity	Continued loss of business for affected firms during flooding.	Slight increase in operating costs with purchase of flood insurance.	Curtailed expansion of existing development in 100-year flood plain areas.	Major long-term adverse disruption to city's commercial-industrial base.	No significant effect.	Continued loss of business for affected firms during flooding.	Long-term beneficial effect with reduced flood damages.	Moderate beneficial effect to existing development.	Moderate beneficial effect with reduced flooding.	Moderate beneficial long-term effect with reduced flooding.
Displacement of Farms	No Effect	No Effect	No effect in project area.	Likely loss of additional farms to accommodate displaced urban development.	No Effect.	No Effect	No Effect	Permanent loss of over 2000 acres of cropland.	Permanent loss of several thousand acres of farm land in reservoir areas.	No Effect.
SOCIAL WELL-BEING										
Health, safety and well-being	Improved safety and well-being with prior and timely flood warnings.	Economic flood losses reimbursed by flood insurance.	Improved safety and well-being via prevention of unwise development in flood plain.	Major disruption of community cohesion and well being due to evacuation and relocation.	Improved security against economic flood damage. Some remaining threat to public safety i.e. attempts to reach inaccessible flood proofed property.	Modest but incomplete protection from flooding. Periodic disruption of community cohesion.	Greatly improved security against flooding and related injury or possible loss of life. Some adverse effect due to steeper driveways along road raise areas.	Significant beneficial effect due to near elimination of flood damage. Adverse effect due to loss of over 2,000 acres of land for channel works.	Beneficial effect due to approximate 20 percent reduction in flood damages. Adverse in reservoir area due to necessary relocation of farmsteads and other residences.	Minor beneficial effect due to flood damage reduction. Major loss of park land and riverine aesthetic values.
Recreational	No Effect	No Effect	Probable increase in recreation and open-space acreage.	Significant gain in park and open-space area in evacuated areas.	No Effect	No Effect	Moderage adverse effect due to park tree losses. Major gain in recreational use at Lincoln Park with barrier around park.	No significant effect.	No effect at Grand Forks - new surface water opportunities in reservoir area.	Adverse substantial loss of parkland acreage.
Historical Resources	No Effect	No Effect	No Effect	Possible loss of structures of local historic significance.	No Effect	No Effect	Reduced flood damage potential to historic structures.	No significant effect.	No effect at Grand Forks, none expected in reservoir area.	No Effect
Archeological Resources	No Effect	No Effect	No Effect	No Effect	No Effect	Possible loss of undiscovered artifacts during construction activities.	Likely disturbance of buried archeological artifacts.	Likely disturbance and removal of buried artifacts.	Likely loss of access to artifacts in reservoirs.	Likely disturbance and removal of buried artifacts.
No. residences relocated	0	0	0	2,200	0	Occasional few.	Purchase of 43 homes along flood barrier alignment.	10	None in project area, unknown number in reservoir area.	0

Table 4 - Comparison of alternatives considered[1] (cont)

Impact Category	Non-Structural					Structural				
	Flood Warning & Forecasting Services	Flood Insurance	Flood Plain Regulation Practices	Permanent Evacuation and Relocation	Flood Proofing	Emergency Flood Fight Activities	Flood Barriers[2]	Floodwater Diversion	Reservoir Storage	Channel Modifications
SOCIAL WELL-BEING Continued:										
No. driveways affected	0	0	0	N/A	N/A	N/A	24	10	0	0
Displacement of people	None	None	None	8,400	No significant effect.	Occasional few.	120-130	30	None in project area, several in reservoir area.	None
Noise	No Effect	No Effect	No Effect	Significant increase for 2-3 years duration of evacuation, demolition and relocation measures.	No Effect	Minor short term increase as a result of construction activities.	Short-term (2-yr) increase due to operation of construction equipment.	Same as Flood Barrier Plan.	No effect in project area.	Same as Flood Barrier Plan.
Esthetic values	No Effect	No Effect	No Effect	Major long-term change in appearance of evacuated areas, increased open space.	No significant effect.	No significant effect over that already experienced.	Permanent alteration of river view with flood barriers and loss of mature trees.	Permanent change to landscape south and west of the City.	No effect in project area.	Long-term adverse effect with removal of river bank tree cover.
Community Cohesion	No appreciable affect.	No Effect	No Effect	Major long-term disruption of long-established community patterns.	No Effect	Temporary disruption during periodic flood fight efforts.	Major long-term beneficial effect with near elimination of costly flood fight activities.	Major changes to established transportation routes.	Minor beneficial effects.	Minor beneficial effect.
Community Growth	No Effect	No Effect	No Effect	Major near-term [illegible] due to relocation of flood prone development.	No Effect	No significant effect.	No significant effect. Some additional development probable in Reach 6.	Considered diversion channel would effect continued urban expansion south and west of the City.	No significant beneficial effect.	No significant beneficial effect.
ENVIRONMENTAL										
Water Quality	No Effect	No Effect	No Effect	Possible long-term beneficial effect due to removal of development.	No significant effect.	Minor short-term increase in turbidity during construction activities.	Temporary increase in turbidity during 2-year construction period.	Temporary increase in turbidity during construction of diversion structure and related channel modification.	Improved due to low flow augmentation.	Temporary adverse effect due to increased turbidity levels.
Effect On Wildlife	No Effect	No Effect	No Effect	Temporary disruption [illegible] mammals and birds in evacuated areas, [illegible] term [illegible] habitat [illegible] mammals and birds.	No significant effect.	Temporary disruption of habitat due to construction activities.	Permanent conversion of small mammal and bird habitat. Loss of mature trees and understory used for cover.	Significant effect on terrestrial species in vicinity of channel. Loss of fence row and ditch cover habitat.	Major adverse in reservoir area. No effect in Grand Forks.	Permanent loss of aquatic and semi-aquatic habitat.
Air Quality	No Effect	No Effect	No Effect	[illegible] levels during removal [illegible] in evacuated areas.	No significant effect.	Very minor increase in pollutant and dust levels during emergency barrier construction.	Temporary increase in dust and pollutant levels during construction period.	Significant increase in dust and combustion product levels during three-year construction period.	No effect in project area.	Temporary increase in dust and pollutant levels during construction period.
Vegetation	No Effect	No Effect	No Effect	No significant effect. Possible [illegible] change in evacuated areas.	No Effect	Very minor and temporary effect.	Significant loss of mature trees in park and residential areas. Also, conversion of ground cover species.	Permanent loss of over 2,000 acres of principally cropland.	No effect in project area.	Loss of flood plain forest understory and stream bank cover.

Table 4 - Comparison of alternatives considered[1] (cont)

Impact Category	Non-Structural: Flood Warning Forecasting Services	Non-Structural: Flood Insurance	Non-Structural: Flood Plain Regulation Practices	Non-Structural: Permanent Evacuation and Relocation	Non-Structural: Flood Proofing	Non-Structural: Emergency Flood Fight Activities	Structural: Flood Barriers[2]	Structural: Floodwater Diversion	Structural: Reservoir Storage	Structural: Channel Modifications
ENVIRONMENTAL (Continued)										
Man-made Resources	No Effect	No Effect	No Effect	Major permanent change to local transportation facilities, and utilities.	No significant effect.	No Effect	Long-term protection against flooding for existing area development.	Same	No effect in project area.	Moderate beneficial effect with limited protection of existing development
Natural Resources	No Effect	No Effect	Reduced vegetation and habitat losses due to curtailment of growth in flood plain areas.	Increased open-space and small mammal and song bird habitat in evacuated area. Some off-setting loss in new development areas.	No significant effect.	No Effect	Some loss of vegetation and habitat along flood barrier routes.	Major loss of cropland.	Major habitat losses in reservoir areas.	Significant area loss of river corridor vegetation and habitat.

1 Compared on the basis of a 100-year flood, figures rounded to nearest $1,000. Annual costs include interest on and amortization of first costs plus average annual operation, maintenance, and replacement costs.

2 Reaches [illegible] only.

3 Variable on the basis of subsequent actions taken.

4 Based on present development only.

5 Not computed because reconstruction costs are not included in first costs. However, the benefit-cost ratio would be less than 1.0.

6 Emergency protection assumed obtainable up to the 50-year flood level. Also includes benefits attributable to reduction in damages between 50- and 100-year flood levels resulting from temporary evacuation of building contents.

7 Includes $422,000 average annual 100-year benefits for East Grand Forks.

8 Includes remaining flood damages in both Grand Forks and East Grand Forks.

October 1977 amendment removed the restrictions on eligibility for mortgages from federally-insured lending institutions for those communities not participating in the program. However, if a community does not participate in the program, property owners may be denied Federal flood disaster assistance funds.

Grand Forks has complied with the requirements for eligibility in the regular program, and flood insurance is available for structures and contents at actuarial rates. As of 31 May 1978, 301 policies were in effect; 220 were for single-family dwellings. Total insurance coverage was $8,892,600.

The 100-year floodplain along the Red River of the North at Grand Forks is generally classified as an A-20 flood insurance rate zone with scattered small areas of B zone in the business district. The English Coulee floodplain includes A and A-11 zones downstream to the Burlington Northern railroad crossing just north of U.S. Highway 2 and A-16 zone from this point downstream to the mouth. Flood insurance can be obtained in maximum coverage amounts of $185,000 and $200,000 for residential and commercial property, respectively. Annual premium rates under the regular program for flood insurance at Grand Forks are shown in the following table.

Table 5 - Annual premiums for flood insurance

Rate zone[1]	Type of insurance: Residential[2]	Type of insurance: Commercial[2]
A	20¢/100 + $15[3]	40¢/100
A-11	25¢/100 + 35¢/100c[4]	40¢/100 + 75¢/100c
A-16	Same as A-11	Same as A-11
A-20	Same as A-11	Same as A-11
B	15¢/100 + 40¢/100c + $15	25¢/100 + 60¢/100c

(1) A zones lie within the 100-year floodplain; a larger appended number (e.g., A-20 compared to A-11) signifies a greater difference between the 100- and 10-year flood depths. B zones lie outside the 100-year floodplain but within the 500-year floodplain.
(2) For a $35,000 maximum coverage, 1-story building with basement.
(3) Expense constant.
(4) 25¢/100 + 35¢/100c = $0.25 per $100 value of building + $0.35 per $100 value of contents.

Floodplain Regulations and Practices

Under the provisions of the regular Flood Insurance Program, eligible communities are responsible for planning, adopting, and enforcing local floodplain regulations. These regulations must minimize future flood damages and may include (1) subdivision regulations, (2) building codes, (3) zoning ordinances, and (4) sanitary regulations. In addition, local governments are encouraged to implement other floodplain management practices such as warning signs, urban redevelopment, open space programs, and public education programs. These ordinances and practices do not necessarily preclude development in the floodplain but rather guide the type and extent of future development permitted consistent with the flood potential.

Grand Forks has adopted a flood zoning ordinance (Ordinance No. 1878 amending and reenacting Article 6, Chapter XIX of the City Code) to ensure regulation and management of flood-prone areas. The ordinance establishes zoning districts for the floodplain and floodway with appropriate permitted uses. The ordinance also requires building permits which recognize the flood hazard and flood-proofing certification based on the "Flood Proofing Code of the City of Grand Forks." An ordinance to regulate subdivision proposals in the flood districts has been drawn up by the City Planning Office but has not been adopted.

Grand Forks has no plans for an urban renewal area or project at the present time. However, the city has assisted with grants and loans to individual home owner-occupied dwellings in the central area of the city bordering on the Red River. It has also purchased some properties adjacent to the Red River for a ring road around the central business district. Some of the acquired property not needed for the road will be developed into a park or open space.

Evacuation and Relocation

Over 2,600 structures are located in the 100-year floodplain in Grand Forks. Over 2,400 are residential, over 200 are commercial or industrial, and about 50 are public.

Permanent evacuation of all damageable flood-prone structures from the floodplain would involve acquisition of lands by purchase, removal and relocation of improvements, evacuation and resettlement of the population, and management and permanent conversion of the lands to uses less susceptible to flood damage. Approximately one-third to one-half of the Grand Forks central business district is in the 100-year floodplain and would require relocation or purchase of existing structures. Roadways and utilities would remain as needed to provide access between adjacent flood-free areas and the evacuated areas which would be converted to open space recreational and other public use.

This alternative would involve the permanent relocation of over 2,400 families and approximately 8,400 residents. Newer development areas for these displaced people would probably be available to the west and southwest of the Grand Forks urbanized area. In addition to the displaced residents, approximately 70 square blocks of the downtown business area and adjacent residential areas would have to be evacuated. Similarly, substantial commercial and industrial development along Mill Road in Reach 5 would require relocation to flood-free property. However, very few of the commercial, industrial, and public structures could be moved. These buildings would be razed with reconstruction accomplished on flood-free lands. Total first costs of required relocations from all 100-year flood-prone areas exclusive of reconstruction costs for nonresidential structures removed are estimated at over $86 million (table 4).

Flood Proofing

This alternative would provide for flood proofing of all suitable structures (sound condition and adaptability to flood-proofing techniques) within the 100-year floodplain in Reaches 1 through 6. Approximately

2,200[(1)] homes, 180 businesses, and 40 public structures could probably be flood proofed. In general, any structure not more than 100 feet within the 100-year flood outline and/or having a first floor elevation not more than 2 feet below the 100-year flood elevation was considered for flood proofing.

Although most simply and economically applied to new construction, flood proofing may be applicable to existing development. Individual residences would be flood proofed by installing drain fields; sealing low-level window, door, and other openings; installing flood drain standpipes and check valves; and sealing and filling in walkout basement entrances. Commercial and industrial structures would be flood proofed with fixed or movable bulkheads across low-level window, door, and utility openings; waterproofing of masonry walls where practical; and elimination of depressed loading ramps where feasible. All costs for required flood proofing measures were determined in accordance with procedures outlined in the Corps of Engineers' publication, "Estimating Costs and Benefits for Non-Structural Flood Control Measures," dated October 1975. Estimated total first costs for this plan would be about $45 million. Assuming 80-percent Federal cost sharing, total Federal first costs would be about $36 million, as shown on table 4.

Emergency Flood Fighting and Relief Activities

Present condition emergency flood fight and disaster relief efforts have been generally successful against past floods. However, a much expanded flood fight and disaster relief effort would have to be instituted for a 100-year flood with a level 4.7 feet higher than the recently experienced April 1978 flood. Thus, this alternative would provide the local emergency effort, assisted by interested agencies, to provide practical protection where possible against a 100-year flood, together with related evacuation and other disaster relief activities.

(1) Excluding approximately 100 residences, 5 public structures, and 25 commercial structures not meeting established criteria.

The Corps-constructed Lincoln Park flood control project protects the Lincoln Drive residential section from all floods up to the 36-year flood. When flood stages are imminent, the city must arrange for the mobilization of personnel, equipment, and supplies necessary to meet impending emergencies. Detailed instructions for inspections, tests, and operation of the project are in the Operation and Maintenance Manual provided to the city of Grand Forks when the project was completed and turned over to the city.

Emergency activities in this area could be the raising of the entire flood barrier about 3.6 feet to provide 100-year protection (with 3 feet of freeboard) or the evacuation of the affected area when a stage greater than 47.8 feet (36-year flood) is imminent. Because time would probably not be available for raising the levee and floodwall, evacuation of the area appears more feasible for predicted high flood stages. Similarly and in view of uncertain soil conditions, raising the Riverside Park and Central Park levees much above their current heights appears questionable. Thus, under this course of action, these areas would also be evacuated when flood stages of 47 and 50 feet, respectively, are imminent. Private flood proofing (sandbagging efforts) in the Belmont Road (Reach 1) and English Coulee areas would be practical only up to the 50-year flood level. Therefore, about 250 and 70 homes, respectively, would be evacuated. Placement of temporary flood barriers and evacuation of people located in the central business district (Reach 4) would begin before a stage of about 42 feet. A summary of principal flood fight activities required at various flood stages is given in the following table.

Total first costs for a local emergency flood fight against a 100-year flood (including post-flood cleanup, restoration, and reconstruction activities) are estimated at $3,800,000, with corresponding average annual costs of $252,000. Because available local resources would not be capable of fighting a major flood, Federal assistance under Public Law 99 could be provided if deemed advisable and certain items of local cooperation are provided to the affected Federal agency. For a massive flood fight, it is assumed that Federal expenditures would be roughly 80 percent of the total or $3 million as shown in table 4.

Table 6 - Flood fight activities

Flood stage (feet)(1)	Required effort
27	Mobilize city manpower and equipment resources. Restrict traffic in low-lying park areas.
27-35	Place closures in the existing Riverside and Central Park levees. Continuously inspect these barriers to quickly locate any areas of foundation subsidence. Provide temporary drainage pumping behind existing emergency levees.
35-40	Evacuate low-lying residential areas.
42	Sandbag NSP plant.
42-47	Install a temporary Grand Forks water supply from East Grand Forks. Evacuate the downtown business district and adjacent residential areas.

(1) Zero gage elevation = 778.35 at river mile 295.7.

Under Public Law 99, Federal assistance can be provided for emergency flood protection when requested by the city and when all their available resources have been exhausted. Resolutions relating to provision of needed rights-of-way, responsibility for damage resulting from the work, and restoration or removal of the flood barriers as required must be supplied by the city.

STRUCTURAL MEASURES

Structural measures considered included flood barriers along the Red River at Grand Forks, a diversion channel to bypass flood flows around the urban area, floodwater storage on the Red Lake River, and channel improvements along the Red River at Grand Forks. All structural measures were analyzed on the basis of the 50-year, 100-year, and standard project floods.

Flood Barriers

Red River main stem flood barriers (including levees, floodwalls, road raises, closures across road and rail crossings, attendant interior

drainage measures, and necessary structure and utility relocations) were considered for the 50-year, 100-year, and standard project flood levels. Flood barriers, with the exception of a stream closure near the mouth, were considered impractical for English Coulee (Reach 6). Barriers were also considered impractical for the portion of Reach 1 south of Lincoln Park (Olson Drive area) because space between affected residences and the river is not sufficient.

All flood barriers considered would provide 3 feet of freeboard over the design flood level. Levee side slopes would generally be 1 vertical on 3 horizontal on the riverward side and 1 on 4 on the landward side. All disturbed areas would be topsoiled and seeded with selected grass species. Typical levee and floodwall cross sections are shown on figure 2.

The following descriptions of the flood barriers proceed northward along the riverbank from the south end of Lincoln Park. Principal features of the plans are cross-referenced by number between the text and figures 3, 4 and 5. Principal flood barrier system data are given in table 7. Summary estimates of first costs and estimated average annual costs are given in attachment A.

100-Year Plan - The considered 100-year flood barrier plan (figure 3) for Reach 1 would include a 2,500-foot raise of Belmont Road [1](1) extending from about 23rd Avenue South northward to 13th Avenue South. The average road raise height would be 6.8 feet. Also included would be a 900-foot floodwall [2] with an average height of 5.3 feet extending from the road raise at 13th Avenue South eastward to Almonte Avenue extended. The road raise would require the raising of about 19 driveway ramps and road ramps at the intersections of 15th and 12th Avenues South. Construction of the road ramps would require the removal of two homes as shown on figure 3. Also included would be a 9,900-gpm interior drainage pumping station with ancillary collection and discharge works. Total estimated first costs for these improvements would be $1,474,000 with corresponding average annual costs for interest, amortization, operation, maintenance, and replacement of $102,000.

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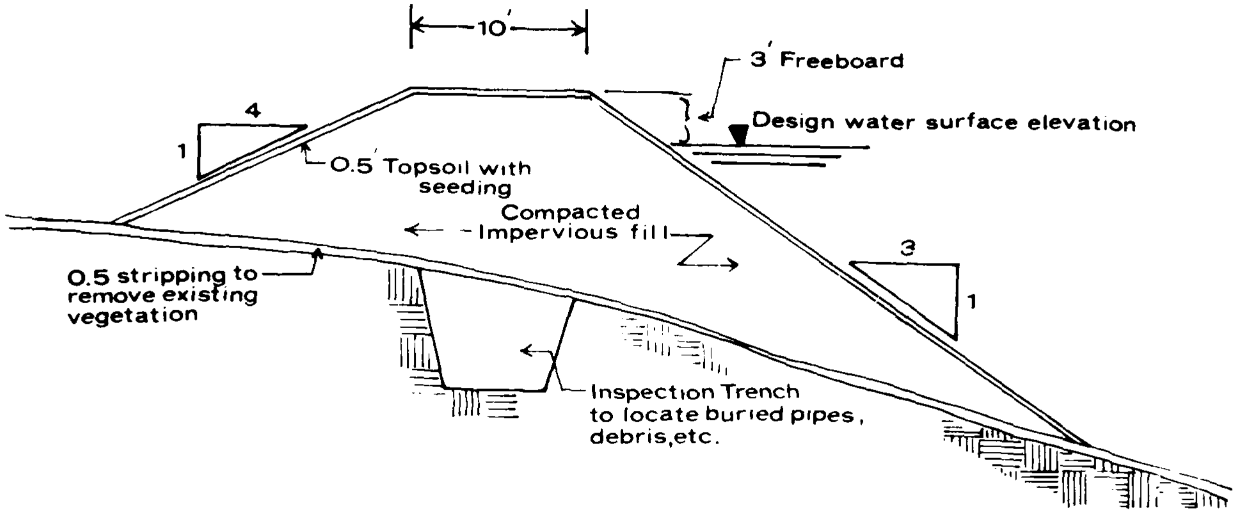
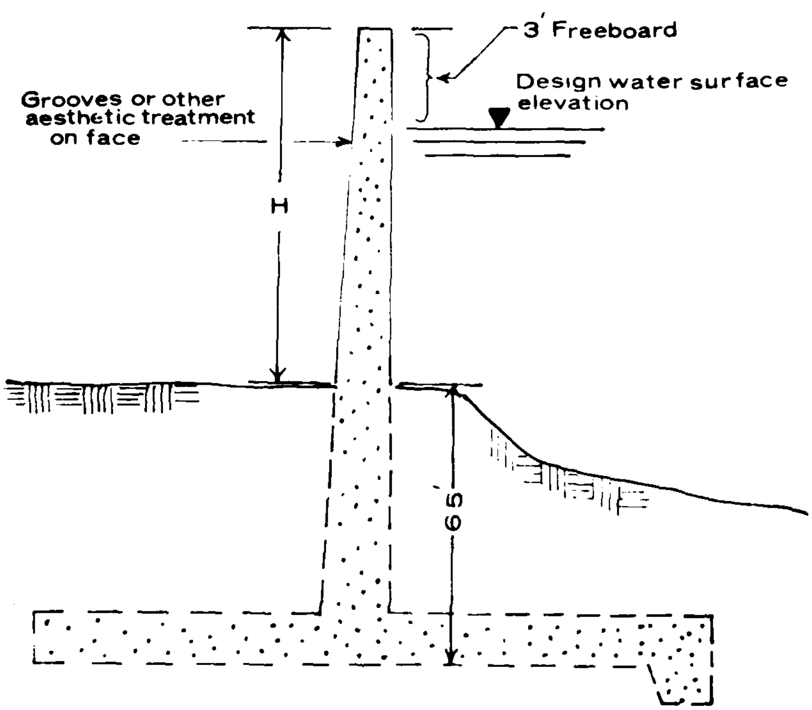
(1) See feature reference number in figure 3.

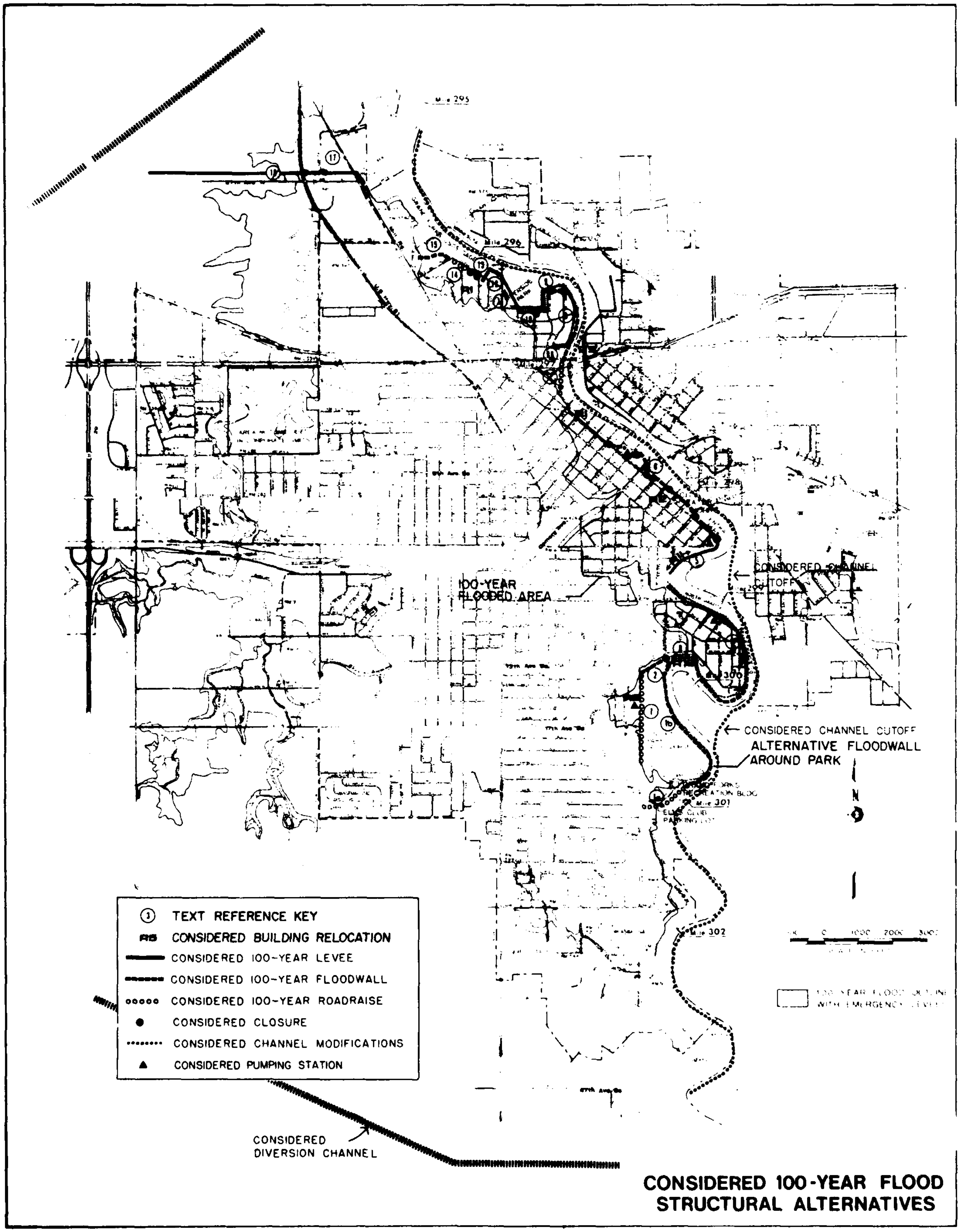


TYPICAL LEVEE SECTION



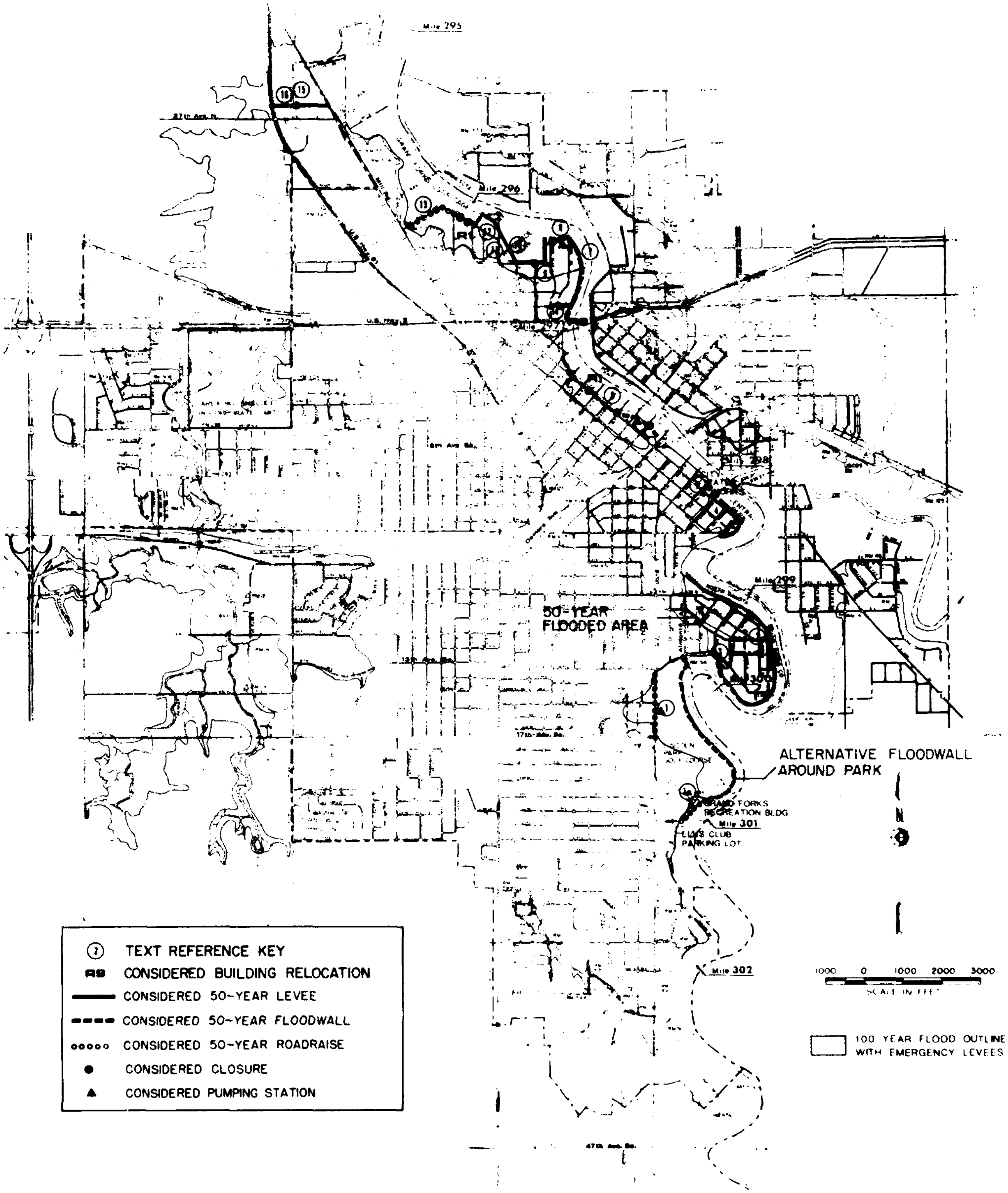
TYPICAL CONCRETE FLOODWALL SECTION

FIGURE 2



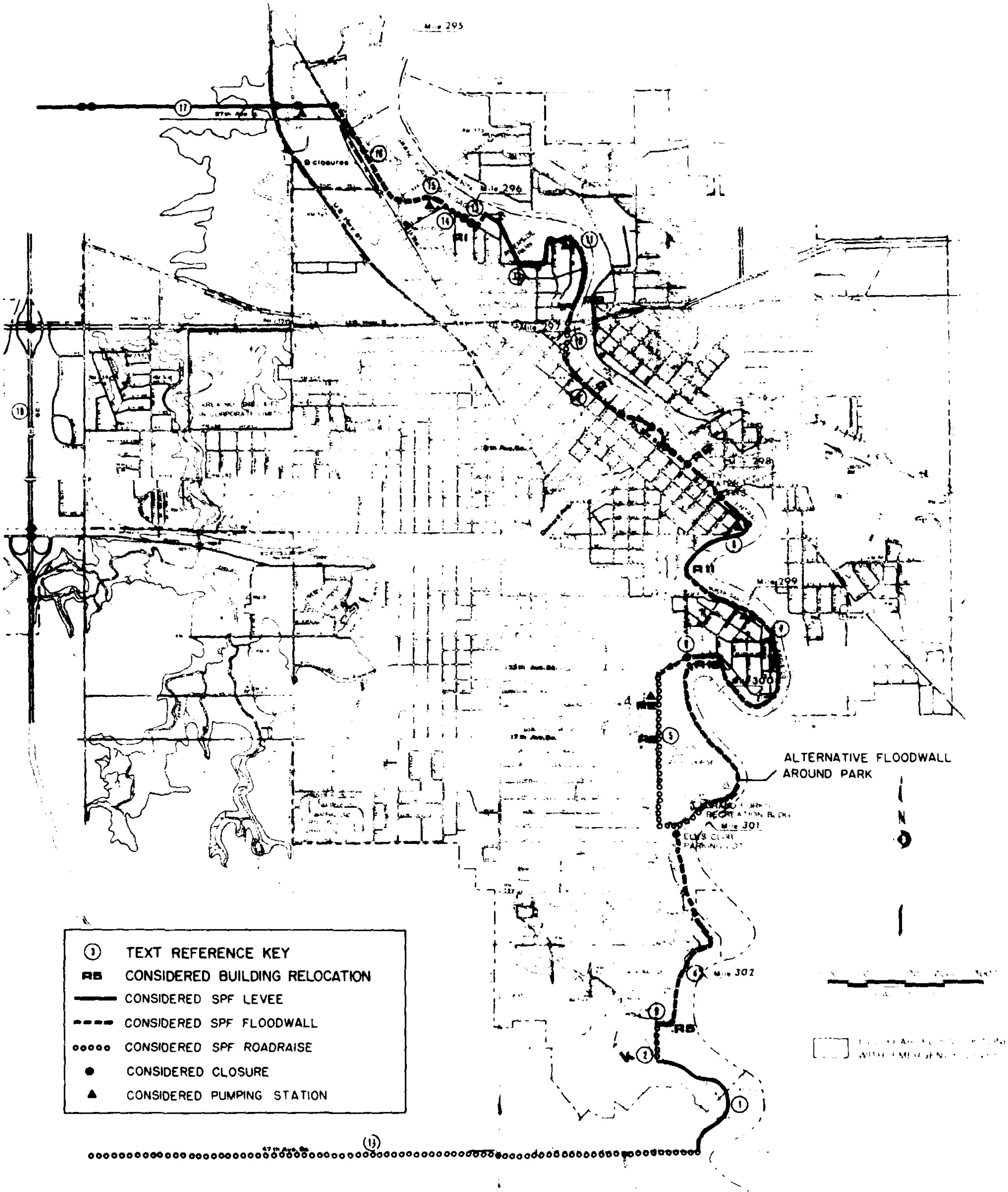
CONSIDERED 100-YEAR FLOOD STRUCTURAL ALTERNATIVES

FIGURE 3



CONSIDERED 50-YEAR FLOOD BARRIER ALIGNMENT

FIGURE 4



CONSIDERED SPF FLOOD
BARRIER ALIGNMENT

FIGURE 5

Table 7 - Technical data for considered flood barriers

	REACH 1		REACH 2		REACH 3		REACH 4		REACH 5		REACH 6		TOTAL FOR ALL REACHES	
	50-year	100-year	50-year	100-year	50-year	100-year	50-year	100-year	50-year	100-year	50-year	100-year	50-year	100-year
LEVEES														
Total length (ft.)	0	0	5160[1]	5160[1]	1800	2840	0	0	3170	3170	2000	6420	12,130	17,590
Average Height (ft.)	--	--	0.9	3.6	7.3	8.3	--	--	8.0	11.1	4.7	5.1	--	--
Land Area Required (acres)	--	--	0.3	1.1	3.3	5.7	--	--	6.1	7.6	2.0	9.0	11.7	23.4
FLOODWALLS														
Total Length (ft.)	0	900	770[2] +30	2250[3]	0	0	2400	4980	2660	4060	0	0	5790	12,890
Average Height (ft.)	--	5.3	0.9	5.4	--	--	3.1	6.4	9.4	9.4	--	--	--	--
Land Area Required (acres)	--	0.4	0.1	0.7	--	--	1.1	2.3	1.2	1.9	--	--	2.4	5.3
CLOSURES														
Number	0	0	0	1	2	2	3	5	4	4	1[4]	1[4]	10	13
Total Length (ft.)	--	--	--	20	80	80	120	180	120	120	80[4]	80	400	489
Required Height (ft.)	--	--	--	5.3	6.2	6.9	4.3	6.2	6.9	9.2	24.7	26.8	--	--
ROAD RAISES														
Total Length (ft.)	1700	2500	0	0	0	0	0	950	1300	800	0	0	3000	4250
Average Height (ft.)	5	6.8	--	--	--	--	--	5.3	3.7	6.0	--	--	--	--
Land Area Required (acres)	2.7	4.6	--	--	--	-	-	1.5	0.3	0.3	--	--	3.0	6.4
INTERIOR DRAINAGE														
Required Pumping Capacity (gpm)	7900	9900	9800	10,300	15,400	20,900	17,300	42,100	44,000	48,400	not evaluated	not evaluated	--	--
STRUCTURE RELOCATIONS														
Residential (number)	0	2	0	20	0	11	0	0	10	10	0	0	10	43
Other (number)	0	--	0	0	0	0	1	3	--	--	0	0	1	3

1 Raise of existing Lincoln Park levee.

2 Raise of existing Lincoln Park floodwall.

3 1,480 feet of new floodwall plus raise of existing 770-foot long floodwall.

4 English Coulee control structure.

An alternative alignment which would protect the Lincoln Park environs and negate the need for a Belmont Road raise was also investigated. This alternative would include raising of the Park Drive [1a] from Belmont Road eastward a distance of about 1,500 feet, thence a 4,700-foot floodwall [1b] with an average height of about 16 feet extending northward along the riverbank to the upstream end of the existing Lincoln Park floodwall. Assuming stable foundation conditions and substituting a 16-foot high levee (122-foot bottom width) for the floodwall would require removal of most of the riverbank tree cover but would be considerably cheaper. Total Reach 1 first costs with the floodwall would be $3,381,000 as compared to $1,067,000 with the substitute levee.

Considered 100-year barrier works along Reach 2 would include a 1,480-foot floodwall [3] with an average height of 5.4 feet extending from Almonte Avenue extended eastward to the existing Lincoln Park floodwall. They would also include raising the existing Lincoln Park floodwall and levee [4] about 3.6 feet. Related measures would include expansion of the capacity of the existing interior drainage works, removal of 18 residences, and a closure structure at Almonte Avenue (park access drive). Total 100-year flood barrier costs for Reach 2 are estimated at $2,602,000.

Considered 100-year measures along Reach 3 would include a 2,840-foot levee [5] with an average height of 8.3 feet extending from a point 200 feet north of the existing Lincoln Park levee generally northward to Minnesota Avenue. Also included would be a 20-foot-wide closure at Third Street extended and a 60-foot-wide closure across Minnesota Avenue. Other related measures would include a 20,900-gpm interior drainage pumping station with ancillary collection and discharge works and the removal of 11 houses. Total first costs for these measures are estimated at $2,265,000.

Reach 4 flood barrier measures would include a continuous 4,980-foot floodwall [6] with an average height of 6.4 feet extending from the Minnesota Avenue closure structure northward to Sixth Avenue North and a 950-foot raise of Seventh Street [7] between the Burlington North railroad crossing and U.S. Highway 2. Other works would consist of five closure structures, including a rail crossing, Demers Avenue crossing, street crossing, and two building access closures. Interior drainage works would include a 42,100-gpm pumping station and necessary collector and discharge works.

Three commercial structures would require removal from the floodwall alignment. Total first cost for the Reach 4 measures is estimated at $4,503,000.

Considered 100-year flood barrier works along Reach 5 (figure 3) would include a 2,260-foot floodwall [8] with an average height of 11.6 feet extending from the U.S. Highway 2 embankment northward along the emergency flood barrier alignment to Riverside Drive, a 520-foot levee [9] along the existing levee alignment between Riverside Drive and Lewis Boulevard, a 1,250-foot levee [10] along the existing levee alignment between Lewis Boulevard and North 2nd Street, an 800-foot levee [11] with an average height of 8 feet extending northwesterly across the park between North 2nd Street and North 3rd Street, a 600-foot levee [12] from North 3rd Street at the west edge of the park extending westerly along high ground, thence a 400-foot floodwall [13] extending southward to Alpha Avenue, an 800-foot raise of Alpha Avenue [14] an average of about 6 feet, and a 1,400-foot floodwall [15] with an average height of 5 feet between Alpha Avenue and North 20th Street. Related measures would include the conversion of 300 feet of local street to flood barrier right-of-way [16] between U.S. Highway 2 and Seward Avenue and the relocation of 200 feet of Riverside Drive north of Seward Avenue. Four closure structures would be required at three locations. Ten homes, nine between U.S. Highway 2 and the existing flood barrier and one on Alpha Avenue, would be relocated. Interior drainage measures would include a 48,400-gpm pumping station and attendant collection and discharge works. Total first costs for Reach 5 structural measures are estimated at $5,312,000.

Considered 100-year structural measures to reduce flood damages along English Coulee (Reach 6) would include an 80-foot gated control structure [17] across the coulee together with 6,500 feet of tie-back levees [18] to high ground as shown on figure 3. The control structure would be constructed of compacted fill along with three 6-foot diameter gated culverts to pass normal flows. The tie-back levees would have an average height of 7.1 feet eastward to Mill Road and 4.5 feet westward to high ground. Also

included would be the temporary ponding of interior drainage runoff including the undiverted English Coulee flow. Total first costs for these measures excluding the cost of interior drainage are estimated at $500,000.

<u>50-Year Plan</u> - Considered 50-year structural flood damage measures for Reach 1 would include raising Belmont Road [1] an average of 5 feet over a distance of 1,700 feet between 17th and 13th Avenues South along with a road ramp at 15th Avenue South and raising of 12 driveway approaches. Also included would be a 7,900-gpm interior drainage pumping station with attendant collector and discharge works and the removal of approximately 20 boulevard trees along Belmont Avenue. Total first costs for these measures are estimated at $502,400 as shown on table A-1.

An alternative flood barrier alignment to protect Lincoln Park and negate the need for the Belmont Road raise was also formulated. This alternative would include raising Park Drive [1a] over a distance of 1,200 feet and a 4,700-foot floodwall [1b] with an average height of 13 feet extending northward along the riverbank to high ground at Almonte Avenue extended as shown on figure 4. A floodwall was first considered in this preliminary review in view of possible unstable riverbank conditions. If, however, foundation conditions are stable, a 13-foot high levee would be considerably less expensive but would require removal of much of the riverbank tree cover. Total first costs for this Reach 1 alternative would be $2,853,000 and $756,000 with a floodwall and levee, respectively.

Considered 50-year flood barrier measures to upgrade the existing Lincoln Park levee would include raising the existing 5,160-foot levee and 770-foot floodwall [2] an average vertical distance of 0.9 foot to provide 3 feet of freeboard over the 50-year flood level. Also included would be a 30-foot extension of the floodwall [3] and minor modifications to existing interior drainage works. Total first costs for these additional Reach 2 measures are estimated at $131,000.

Considered 50-year flood barrier works in Reach 3 would include a 1,800-foot levee [4] with an average height of 7.3 feet along the emergency levee alignment. Other related works would include a 20-foot wide closure structure at Third Street extended and a 60-foot wide closure across Minnesota Avenue and interior drainage works consisting of 15,400-gpm pumping station and collector and discharge facilities. Total first costs are estimated at $1,075,000.

Measures to provide a 50-year level of protection for the central business district (Reach 4) would include a 100-foot floodwall [5] extending westward from the Minnesota Avenue closure structure, a 2,300-foot floodwall [6] with an average height of 3.1 feet extending northward along the riverbank from a point 200 feet south of Demers Avenue to a point on the bank across from North Sixth Avenue, a 60-foot closure structure across Demers Avenue, a 40-foot wide closure across Second Avenue, a building access closure at Fifth Avenue, and the removal of one structure at Fifth Avenue North. Also included would be 17,300-gpm pumping station with attendant collector and discharge works and modifications to existing utilities. Total Reach 4 first costs would be $1,728,000.

Reach 5 measures would include a 2,260-foot floodwall [7] with an average height of 9.4 feet between U.S. Highway 2 and Riverside Drive, a 520-foot levee [8] between Riverside Drive and Lewis Boulevard, a 1,250-foot levee [9] with an average height of 7 feet between Lewis Boulevard and North Second Street, an 800-foot levee [10] with an average height of 4 feet extending northwesterly across the park between Second and Third Streets North, thence a 600-foot levee [11] extending westward, a 400-foot floodwall [12] extending southward to Alpha Avenue, and a 1,300-foot raise (3.7 feet) of Alpha Avenue [13]. Other required works include the conversion of 300 feet of local street to floodwall right-of-way [14] between U.S. Highway 2 and Seward Avenue and the relocation of 200 feet of Riverside Drive north of Seward Avenue. Four closure structures would be required at three locations. Ten homes would be removed from the flood barrier alignment. A 44,000-gpm interior

drainage pumping station would remove runoff behind the flood barrier. Total first costs for these measures are estimated at $4,335,000 as shown in table A-1

Standard Project Flood Plan - Protection of individual reaches at Grand Forks against the standard project flood (SPF) would be impossible because of the flat topography. Thus, the standard project flood barrier would be essentially a "ring" barrier system around the city as shown on figure 5.

This system would include a 4,260-foot levee [1] with an average height of 13.5 feet along the riverbank between 27th Avenue South extended and Belmont Road, a 400-foot road raise [2] over Belmont Coulee, a 650-foot levee [3] eastward from Belmont Road, a 5,900-foot floodwall [4] with an average height of about 15 feet northward to the park access drive at Lincoln Park, a 3,800-foot raise of Belmont Road with an average height of 14.7 feet [5], a 3,150-foot floodwall [6] with an average height of 13.7 feet eastward from Belmont Road to the existing floodwall, raising of the existing floodwall and levee [7] about 12 feet, a 3,040-foot levee [8] with an average height of about 16 feet around Central Park to Minnesota Avenue, a 5,780-foot floodwall [9] with an average height of 13.7 feet between Minnesota Avenue and 7th Avenue North, a 1,050-foot road raise along 7th Avenue [10], a 2,260-foot floodwall [11] with an average height of 18 feet between U.S. Highway 2 and Riverside Drive at Riverside Park, a 3,170-foot levee [12] with an average height of 15 feet between Riverside Drive and a point 600 feet west of North 3rd Street at the west end of the Riverside Park, thence a 400-foot floodwall [13] southward to Alpha Avenue, an 800-foot raise (11 feet) of Alpha Avenue [14], and a 1,400-foot floodwall [15] from the Alpha Avenue raise to the vicinity of North 20th Street. From that point, a system of floodwalls [16] with a total length of about 2,900 feet and nine closures would pass between Mill Road and adjacent riverward structures to a point on Mill Road about 300 feet north of 27th Avenue North. A 7,500-foot [17] levee would then extend westward to the Interstate Highway 29 (I-29) embankment along with closures shown on figure 5. The I-29 highway embankment between 27th Avenue North and 47th Avenue South along with suitable closures would be used as a flood barrier.

Lastly, a 15,200-foot raise (6.6 feet) of 47th Avenue South [19] between the I-29 embankment and riverbank levee would complete the system. Other measures would include an extensive interior drainage system, numerous closures as shown on figure 5, the relocation of 50 homes and other structures, the raising of 40 driveway approaches, and required utility relocations. Total first costs are estimated at $68,384,000.

From table 7, it is evident that substantial amounts of floodwall are required in Reaches 4 and 5. Floodwall is considered most appropriate for Reach 4 because of area constraints in the densely developed urban area. Floodwall in lieu of levee is dictated for the Riverside Park area primarily because of unstable riverbank conditions in contrast to the Mill Road area where space limitations require a floodwall. Road raises are considered in Reach 1 (Belmont Road and 47th Avenue South) and in Reach 5 (Park Drive and Alpha Avenue) to reduce acreage requirements and mature tree losses in Lincoln and Riverside Parks, respectively. Stop-log closures are considered for the heavily travelled thoroughfares whereas road ramps are considered to suffice for slower speed and less frequently traveled park drives.

Diversion Channel

A diversion channel constructed around the west side of Grand Forks (figure 3) would carry all Red River flood flows in excess of the 27,000-cfs bank-full capacity. The 13.7-mile channel would commence at a point about 1.5 miles upstream of 47th Avenue South and reenter the natural channel at a point 3.2 miles downstream of 27th Avenue North extended. The channel would divert 47,000, 62,000, and 199,000 cfs for the 50-year, 100-year, and standard project flood flows, respectively. The grassed channel would be trapezoidal with 1 on 2.5 side slopes and have an average depth (with 2 feet of freeboard) of 20 feet and average bottom widths of 730, 1,140 and 1,440 feet for the 50-year, 100-year and standard project flood flows, respectively.

The considered floodway would require two crossings of I-29 and U.S. Highway 81 and one crossing of U.S. Highway 2. The considered alignment would also cross railroad track at four locations and numerous county, township, and private roads. Local drainage ditches along with English Coulee would require adjustable closures at their intersection with the diversion channel. The floodway would, in addition to diverting flood flows, possibly serve as a repository for urban stormwater runoff and, if water were allowed to remain in the channel, a partial water supply for selected uses and open water body for recreation uses.

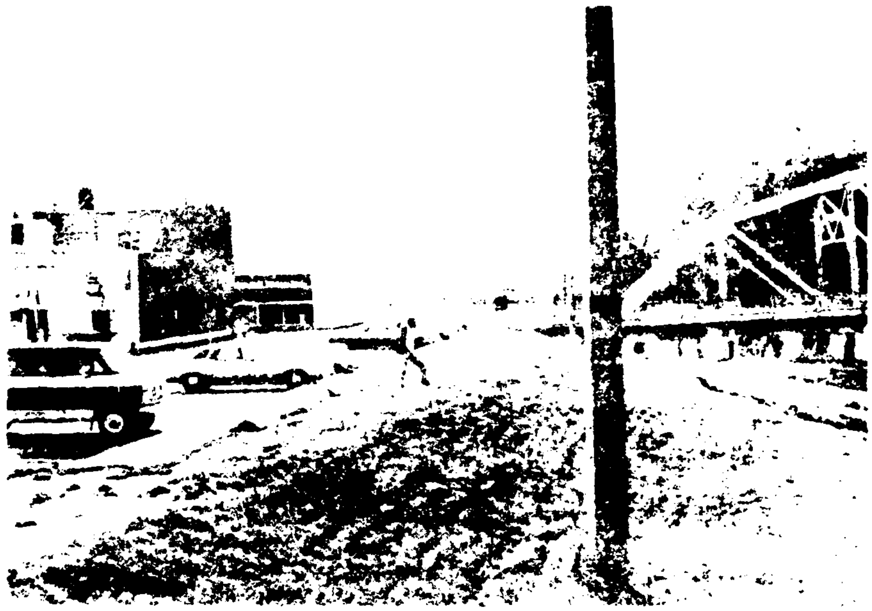
To divert the required amount of floodwater into the floodway, a movable gate diversion structure approximately 700 feet long would be placed across the natural Red River channel at the point of diversion. This structure would permit normal passage of flows less than 27,000 cfs.

Reservoir Storage

Red Lake River flows account for about 45 percent of the average Red River flow at Grand Forks. Of the 50-year and 100-year Red River flows, the Red Lake River contributes about 39 and 38 percent, respectively. Thus, it appears that temporary detention of Red Lake River flood flows in an upstream reservoir would reduce peak flood stages at Grand Forks and East Grand Forks.

Similar opportunities for temporary floodwater storage exist on other major tributaries; authorized detailed planning studies are under way for reservoirs on the Wild Rice River, Minnesota, and the Sheyenne River in North Dakota. A relatively recent unpublished study by the Corps of Engineers indicates that a 1.0-foot reduction in peak flood stages for the 100-year flood could be achieved at Grand Forks with a considered reservoir on the upper Red Lake River. Current studies of the Wild Rice and Sheyenne reservoirs indicate that addition 100-year stage reductions of 0.5 foot could be obtained at Grand Forks from each of these reservoirs.

Several possible modifications of the Red River channel through the Grand Forks-East Grand Forks area were considered. One plan would include extensive widening and deepening measures together with two channel cut-offs across channel meanders as shown on figure 3. This plan would require a finished channel bottom width of around 1,200 feet to pass the 100-year flood discharge. All road and rail bridges crossing this reach would need extensive modifications.

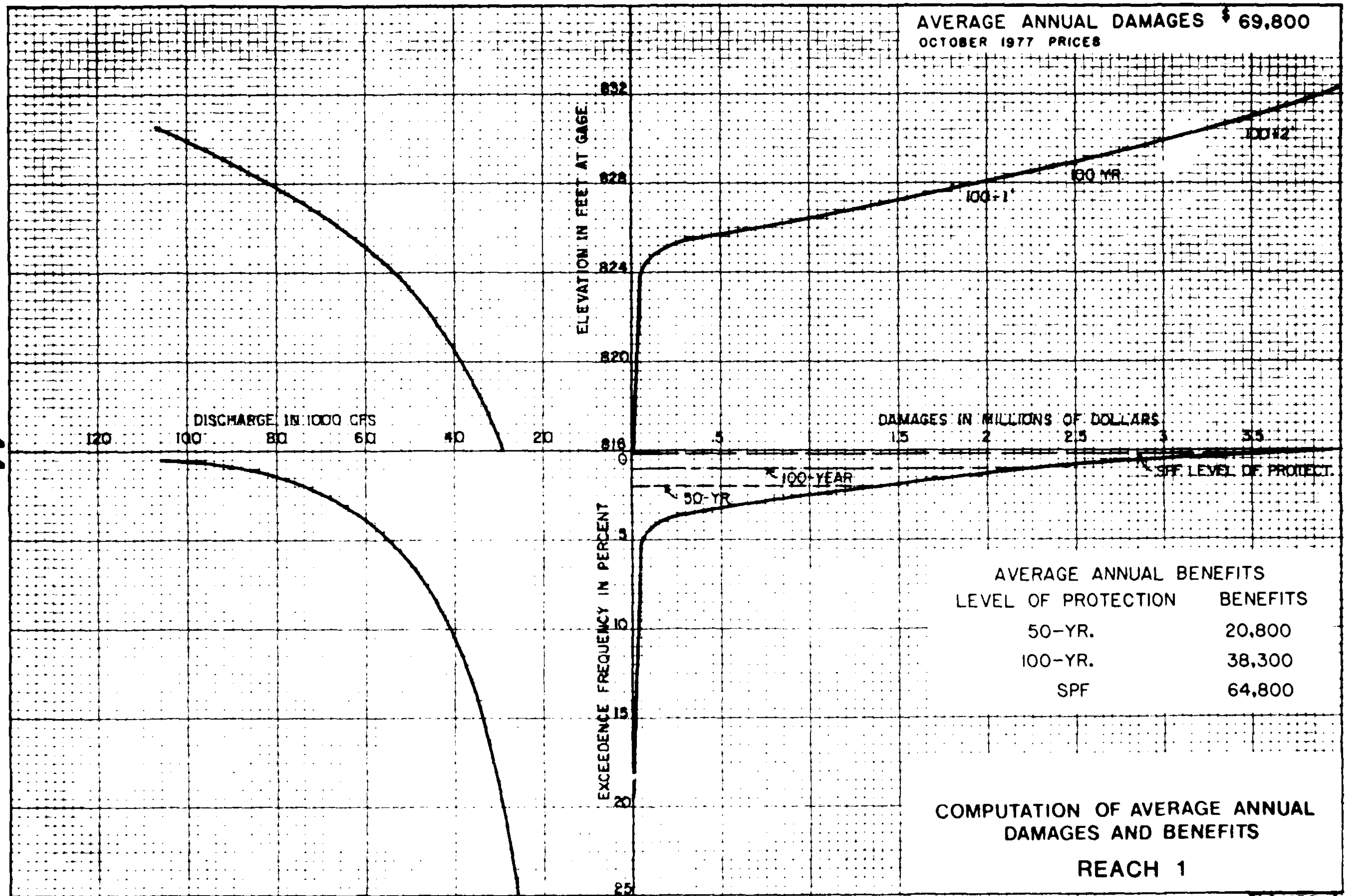


Demers Avenue Bridge - East Grand Forks approach. Note commercial development at bridge approach.

IMPACTS OF CONSIDERED ALTERNATIVES

NONSTRUCTURAL ALTERNATIVES

The following paragraphs discuss the principal economic, environmental, and social well-being impacts of the considered alternatives. A matrix displaying the plan effects is given in table 4. Estimated average annual flood damages for Reaches 1 thru 6 were derived from elevation-discharge, elevation-damage, frequency-discharge and frequency-damage relationships displayed on figures 6, 7, 8, 9, 10, and 11, respectively. Average annual present-condition benefits attributable to the considered flood damage reduction measures are also shown on these same plates. Average annual damages and benefits are given in table A-6.



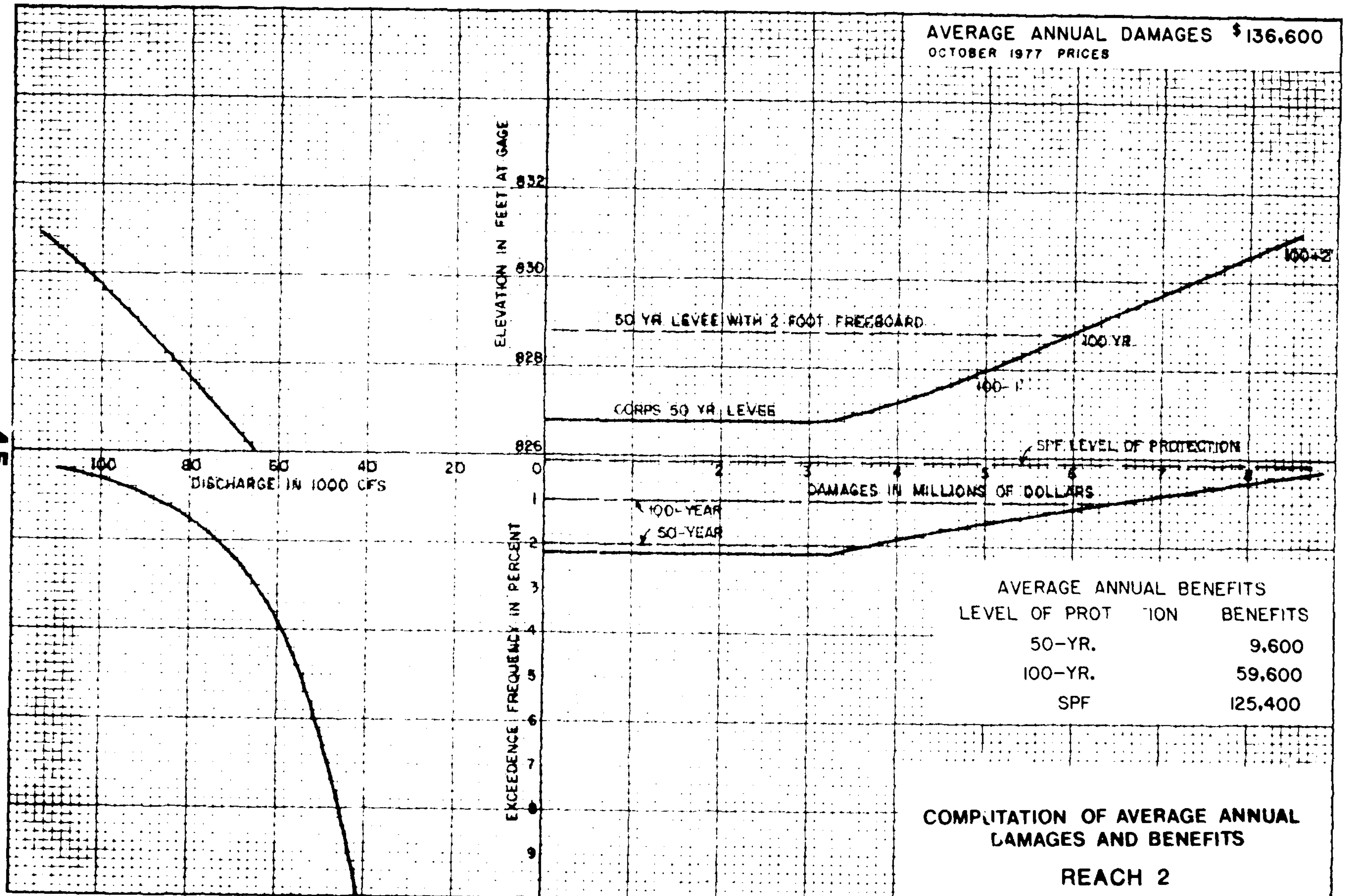
AVERAGE ANNUAL BENEFITS

LEVEL OF PROTECTION	BENEFITS
50-YR.	20,800
100-YR.	38,300
SPF	64,800

COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS

REACH 1

FIGURE 6



AVERAGE ANNUAL DAMAGES $136,600
OCTOBER 1977 PRICES
ELEVATION IN FEET AT GAGE
832
830
828
826
50 YR LEVEE WITH 2 FOOT FREEBOARD
CORPS 50 YR LEVEE
100+2'
100 YR
100-1'
SPF LEVEL OF PROTECTION
100-YEAR
50-YEAR
DISCHARGE IN 1000 CFS
100
80
60
40
20
0
DAMAGES IN MILLIONS OF DOLLARS
2
3
4
5
6
7
8
EXCEEDENCE FREQUENCY IN PERCENT
1
2
3
4
5
6
7
8
9
AVERAGE ANNUAL BENEFITS
LEVEL OF PROT ION BENEFITS
50-YR. 9,600
100-YR. 59,600
SPF 125,400
COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS
REACH 2

FIGURE 7

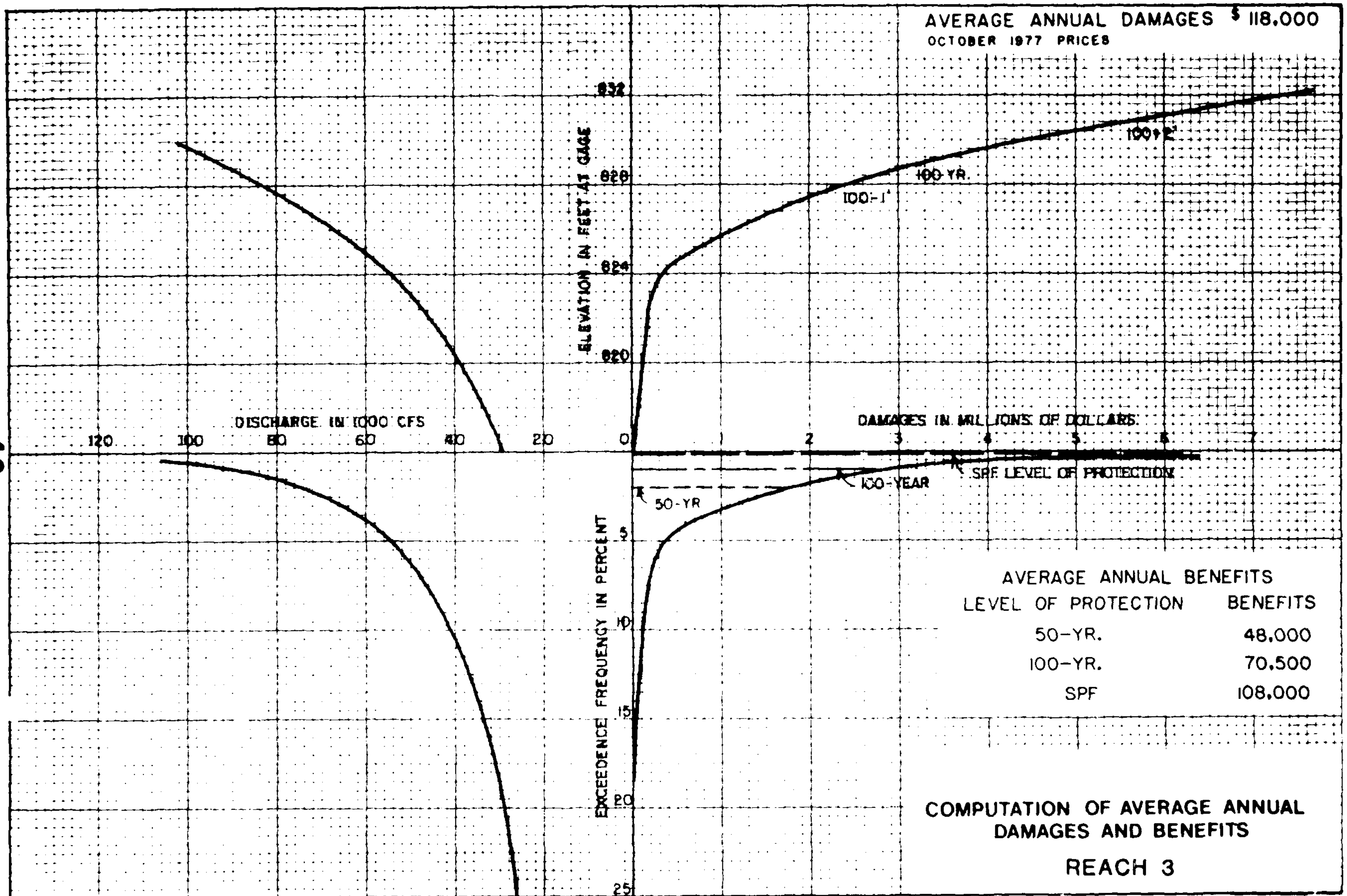

AVERAGE ANNUAL DAMAGES $ 118,000
OCTOBER 1977 PRICES
ELEVATION IN FEET AT GAGE
832
828
824
820
DISCHARGE IN 1000 CFS
120
100
80
60
40
20
0
DAMAGES IN MILLIONS OF DOLLARS
1
2
3
4
5
6
7
100+2'
100-YR.
100-1'
SPF LEVEL OF PROTECTION
100-YEAR
50-YR
EXCEEDENCE FREQUENCY IN PERCENT
5
10
15
20
25
AVERAGE ANNUAL BENEFITS
LEVEL OF PROTECTION BENEFITS
50-YR. 48,000
100-YR. 70,500
SPF 108,000
COMPUTATION OF AVERAGE ANNUAL
DAMAGES AND BENEFITS
REACH 3

FIGURE 8

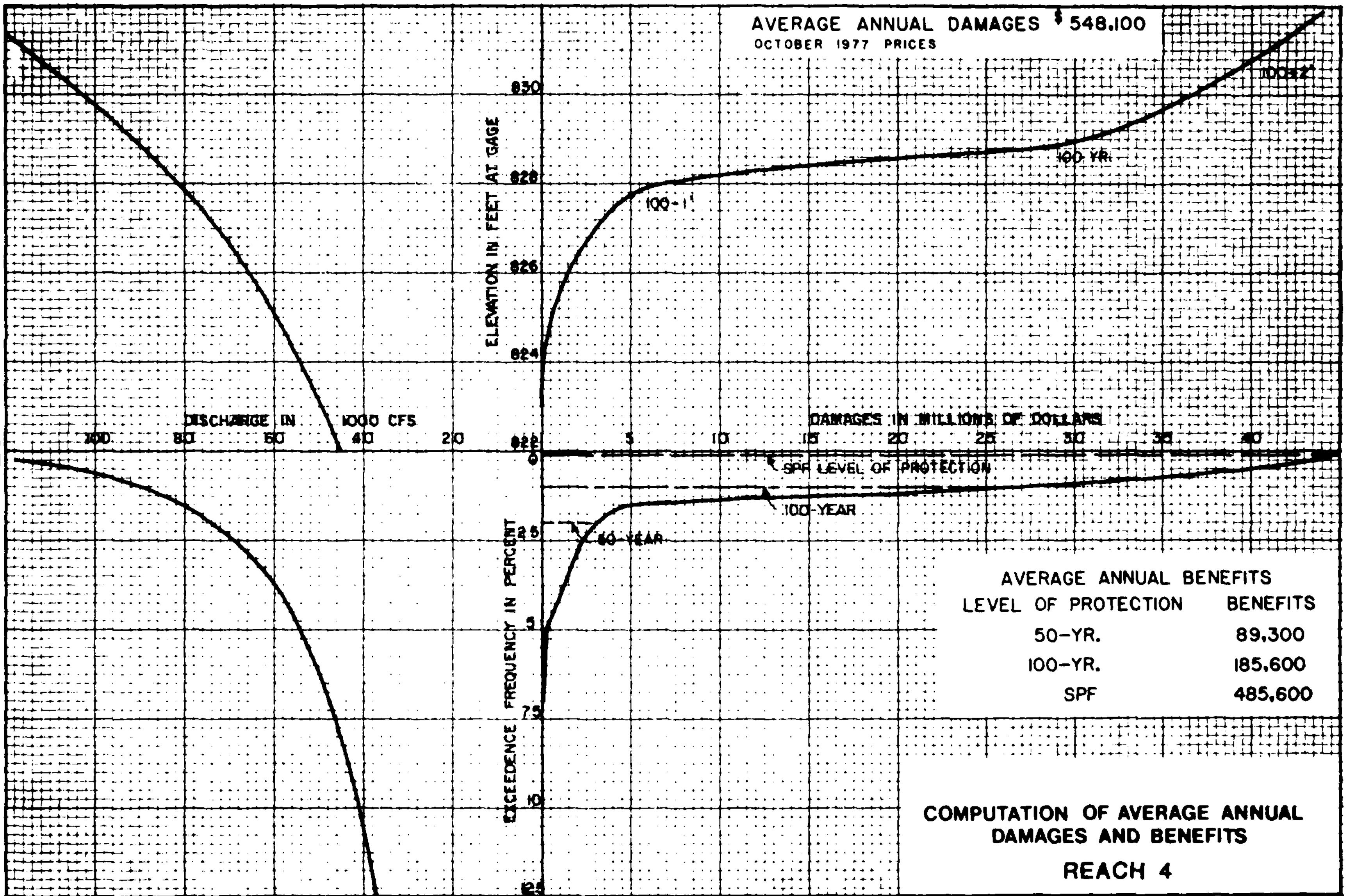

AVERAGE ANNUAL DAMAGES $548,100
OCTOBER 1977 PRICES
ELEVATION IN FEET AT GAGE
830
828
826
824
822
DISCHARGE IN 1000 CFS
100
80
60
40
20
DAMAGES IN MILLIONS OF DOLLARS
0
5
10
15
20
25
30
35
40
100-1'
100 YR.
100+2'
SPF LEVEL OF PROTECTION
100-YEAR
50-YEAR
EXCEEDENCE FREQUENCY IN PERCENT
2.5
5
7.5
10
12.5
AVERAGE ANNUAL BENEFITS
LEVEL OF PROTECTION BENEFITS
50-YR. 89,300
100-YR. 185,600
SPF 485,600
COMPUTATION OF AVERAGE ANNUAL
DAMAGES AND BENEFITS
REACH 4

FIGURE 9

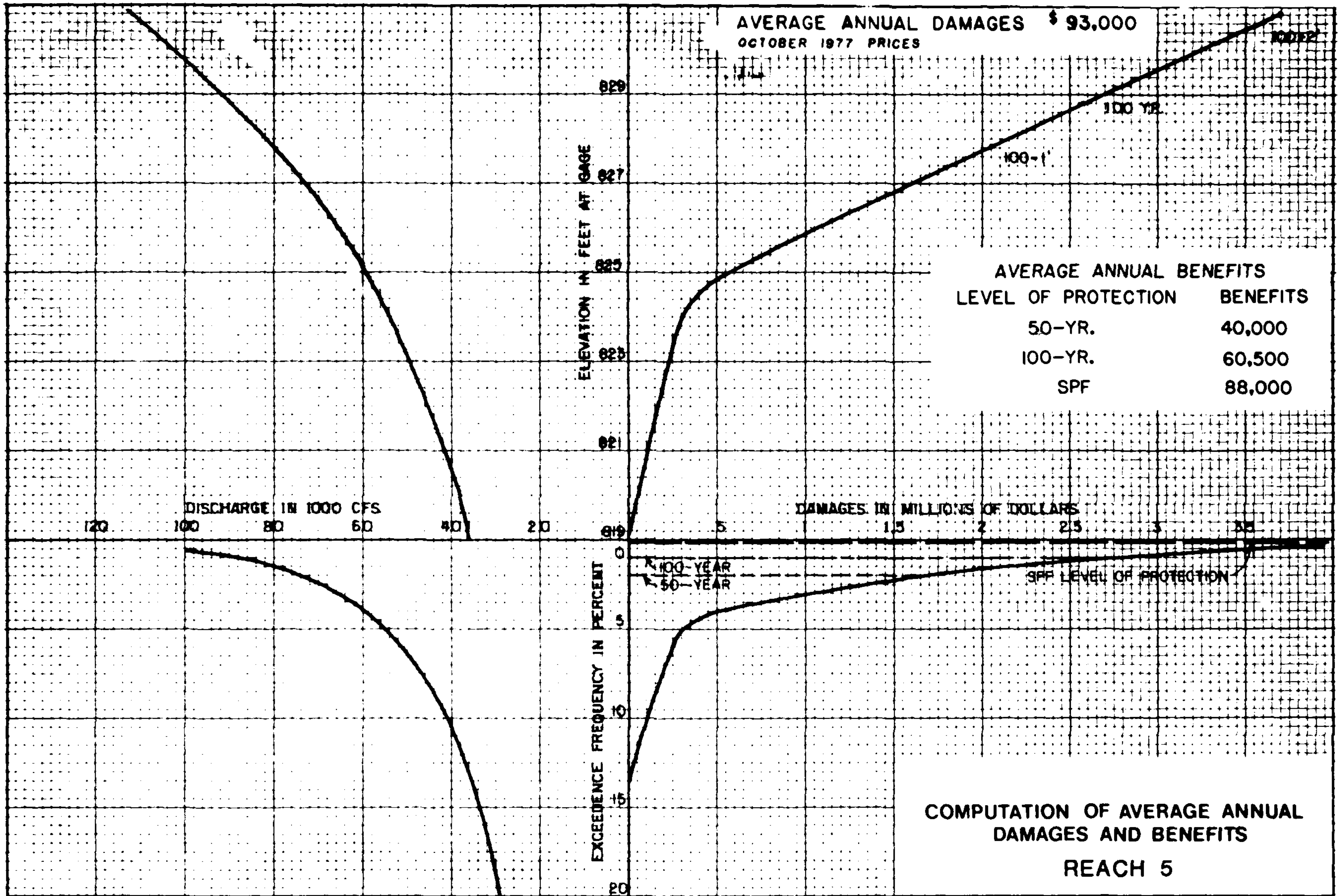
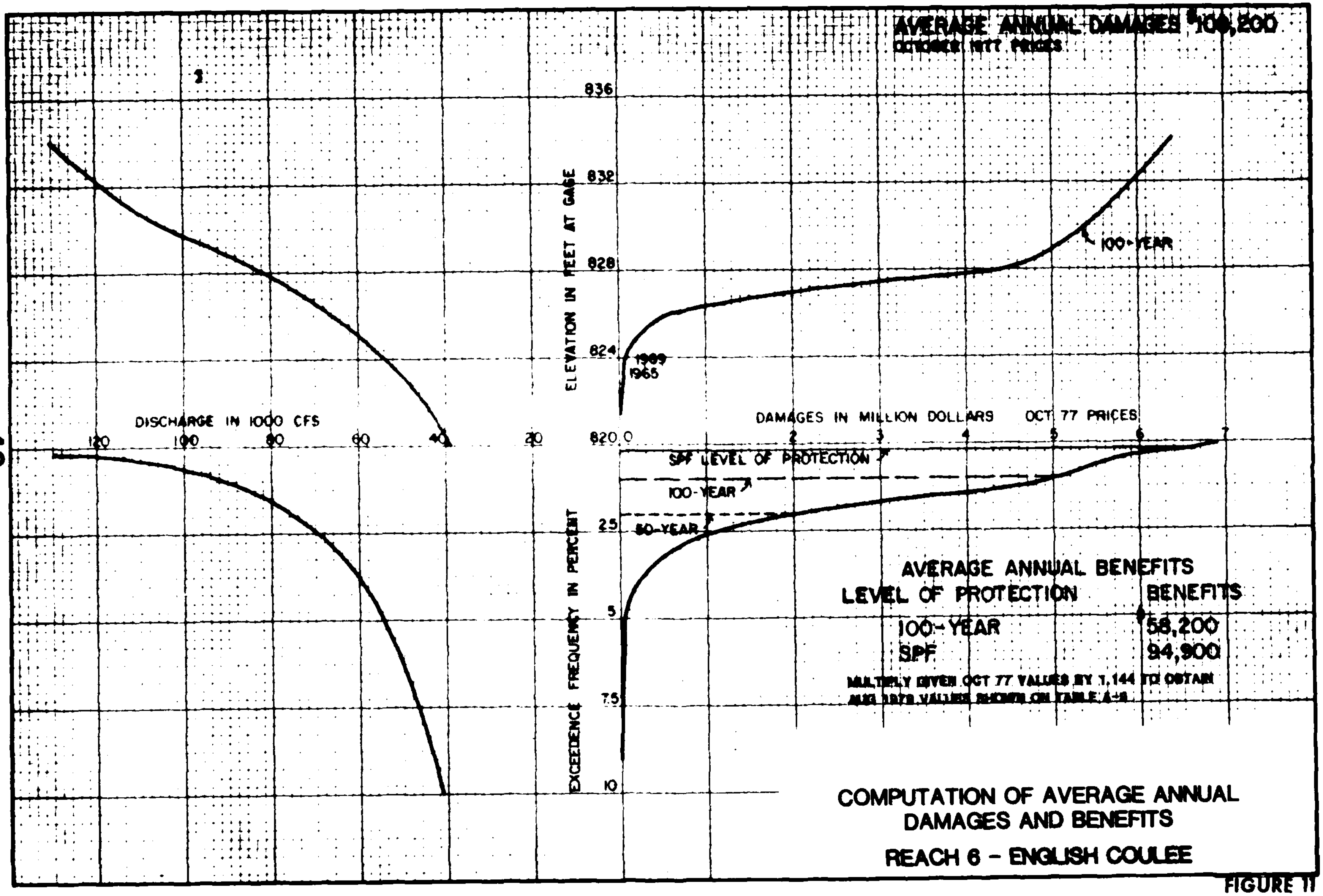

AVERAGE ANNUAL DAMAGES $ 93,000
OCTOBER 1977 PRICES
AVERAGE ANNUAL BENEFITS
LEVEL OF PROTECTION BENEFITS
50-YR. 40,000
100-YR. 60,500
SPF 88,000
100 YR.
100-1'
DISCHARGE IN 1000 CFS
120
100
80
60
40
20
DAMAGES IN MILLIONS OF DOLLARS
.5
1.5
2
2.5
3
ELEVATION IN FEET AT GAGE
829
827
825
823
821
819
EXCEEDENCE FREQUENCY IN PERCENT
0
5
10
15
20
100-YEAR
50-YEAR
SPF LEVEL OF PROTECTION
COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS
REACH 5

FIGURE 10



COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS

REACH 6 - ENGLISH COULEE

FIGURE 11

To maintain the current situation at Grand Forks (i.e., the no action alternative) would include continuance of existing flood insurance, floodplain regulation, and emergency flood fight and disaster relief programs. Without additional measures, the city of Grand Forks remains subject to substantial property damage and hazards to public safety. Estimated remaining average annual damages with the no action alternative exceed $1 million. The following paragraphs on flood warning and forecasting, flood insurance, floodplain regulations and practices, and emergency flood fighting and relief activities provide a discussion of the residual impacts and effects expected with sole reliance on these existing measures.

Flood Warning and Forecasting Services

The costs of administering the flood warning and forecasting services are borne by the Federal Government. This National Weather Service program will continue to be invaluable in forecasting the timing, incidence, and expected magnitude of impending Red River flood crests at Grand Forks. By providing ample warning, emergency flood fight and disaster relief activities may be undertaken to reduce potential flood damage and threats to public health and safety. However, with this measure alone, substantial existing development, such as homes (Reach 1), businesses (Reach 4), and utilities and transportation facilities (all reaches) not readily protected against flooding would remain subject to damage. Estimated average annual remaining damages (assuming that adequate warnings would enable a partially successful flood fight resulting in a 10-percent reduction in damages) would be about $967,000 (table 4). Further, the periodic commitment of emergency relief activities would place a continued burden on area manpower, financial and material resources. Local resources, already in short supply, must be periodically and inefficiently diverted from ongoing public maintenance or operation programs or needed capital investment projects to conduct a temporary flood relief program at Grand Forks. No significant adverse or beneficial environmental impacts would result from this continued action.

Flood Insurance

The regular phase flood insurance program in effect at Grand Forks compensates enrolled property owners for flood damages. Recent information indicates a relatively small enrollment in the program with primary emphasis on new floodplain construction and/or major remodeling of existing structures.

This program does not reduce the actual threat of property damage or hazards to public health and safety. The worry and anxiety during floods would continue. Remaining average annual damages of about $1,074,000 are anticipated with this program and current floodplain regulations in effect. No significant environmental changes are expected as a result of continued local involvement in this program.

Floodplain Regulations and Practices

Regulations are in effect as discussed earlier and will continue to ensure that future development in the floodplain will comply with zoning, subdivision, and building code provisions to minimize future flood damages. Costs of this program are largely borne by the city with some reimbursement by individuals for permits and inspection services. Although expected to be effective for new development or major modifications to existing floodplain development, this measure would not materially reduce potential flood damages to the substantial existing public and private flood-prone development. Further, the constant threat to public health and safety resulting from attempted access to and from flooded structures, electrical shock hazards, etc., would remain as is. Average annual damages with this alternative remain at about $1,074,000.

Evacuation and Relocation

Total initial costs in excess of $86 million would be shared on an assumed 80-percent Federal/20-percent non-Federal basis. Subsequent annual costs for management of the new open space and recreation areas would be a non-Federal or city expense. This alternative would nearly eliminate recurring flood damages except for remaining damages to public utilities and transportation facilities but result in a multi-year disruption of the city's and region's financial and retail trade base with removal and relocation of the downtown business area. It would also result in a sharp drop in area employment and income because of lost employment opportunities. The excavated areas would probably benefit

biologically as a result of a slow reinvasion of biotic communities. But, in turn, the new farmland area required for relocation of the several hundred structures would result in loss of productive cropland and wildlife habitat (principally fencerows and windbreaks). The urbanized area would experience a sudden gain in parkland area, not a critical need at present.

The considered relocation of over 8,400 residents would have a long-term adverse effect on established community cohesion and result in the injurious displacement of people away from their current focus of employment and social activity. It would require the construction of a new transportation and utility network at immense local and Federal expense. It is considered very unlikely that the Grand Forks community's financial and other resource base could support a massive relocation.

Flood Proofing

Flood proofing costs (table 4) would also be shared on an assumed 80-percent Federal/20-percent non-Federal basis. Total average annual flood damage reduction benefits with this alternative are estimated at $966,000. A comparison of these benefits with related average annual costs of $3,143,000 indicates an unfavorable benefit-cost ratio of 0.3. Further, a significant potential for hazards to public safety and health would remain with dangerous and interrupted access to inaccessible flood-proofed structures during flooding, vector production, electrocution potential, and damage to transportion and utility facilities. Flood proofing of selected residential structures along English Coulee between North 6th and 11th Avenues, commercial structures along Shakespeare Road south of U.S. Highway 2, commercial structures just downstream of U.S. Highway 2, and commercial-industrial structures near the mouth (U.S. Highway 81 and Mill Road area) appears more practical for the scattered structures in these areas of Reach 6. These areas are not as severely affected by rapid overland flows, and most of these structures border the 100-year floodplain and are generally accessible to immediate high ground. Flood proofing of 50 to 60 residential structures along Olson and Elmwood Drives along Belmont Coulee also appears to present the most technically and economically viable course of action for these areas.

Emergency Flood Fighting and Relief Activities

This alternative, conducted on an as needed basis in accordance with prior flood warnings, would generally be a local effort with assistance from State and Federal agencies. This plan would modestly reduce flood damages (emergency barriers considered practical up to about the 50-year flood level). Resultant plan 100-year benefits would include about $249,000 in reduced damages up to the 50-year level plus $56,000 attributable to reduced damages between the 50-year and 100-year flood levels resulting from the temporary relocation of some building contents from threatened areas. A potential for severe economic flood losses and threats to public health and safety exists with any construction of emergency barriers in this area because widespread adverse riverbank foundation conditions could easily result in failure of the hastily constructed barrier. Failure of an emergency barrier containing a high flood flow would result in extensive losses caused by the sudden onrush of suddenly released floodwaters in what were considered "protected" areas. These measures could constitute a false sense of security against flood damage for area residents, thus requiring very careful planning and implementation on a continuing basis.

STRUCTURAL ALTERNATIVES

Flood Barriers

The considered flood barrier systems would effectively reduce flood damages for the 50-year, 100-year, and standard project flood levels. Protection of individual reaches could practically be accomplished up to the 50-year flood level. A 100-year level of protection could be provided for Reaches 1, 2, 5, and 6 with a combined barrier plan required for Reaches 3 and 4. A standard project flood level of protection can realistically be considered only for the entire flood-prone area. A summary of total 100-year plan first costs, Federal first costs, and non-Federal first costs for Reaches 1 through 5 is given in table 4. Cost data for Reach 6 measures will be determined in future studies after development of a suitable interior drainage plan.

The considered 50- and 100-year flood barriers would provide varying degrees of flood damage reduction benefits in the study reaches. A summary of reduced flood damages for the 50- and 100-year flood levels is given in table 8. The derivation of flood damage reduction benefits for Reaches 1 through 6 is illustrated on figures 6 through 11.

From table 8 it is evident that total 50- and 100-year average annual flood damages for all reaches would be reduced 23 and 44 percent, respectively. 100-year flood damage reduction in percent for individual reaches is given in table A-2. Total average annual benefits attributable to protection against a standard project level flood would be approximately $966,700 representing a 90-percent reduction in average annual flood damages.

The considered flood barrier measures would reduce the recurring threat to public health and safety and disruptions to established community patterns during flood emergencies. The forced displacement of people, hasty construction of emergency barriers, disrupted traffic patterns, and postflood cleanup would essentially be eliminated.

The 50-year flood barrier would be the least obtrusive in terms of height ranging from 3 feet in Reach 4 to 15 feet in Reach 5 (where the average height is 6.8 feet) and require about 17 acres of land (including 7.4 acres for road raises) and nine transportation route and building access closure structures. Moderate tree losses would occur in the vicinity of the Belmont Road raise (Reach 1) and Riverside Park. About 20 boulevard trees would be removed along Belmont Road with minor long-term losses to small mammal and songbird habitat. Vegetative and habitat losses in the Central and Riverside Park areas would be minimal because the levee and floodwall alignment is occupied by the emergency levees. A total of 10 residences and 1 commercial structure would have to be removed from Reaches 1 through 5.

The alternative flood barrier alignment to include protection of Lincoln Park would eliminate the need for a Belmont Road raise with 12 related driveway grade raises. However, a levee along the riverbank would require the

Table 8 - Summary of 50- and 100-year flood damage reduction benefits

Reach	Existing condition average annual damages	50-year flood barriers: Project condition average annual damages	50-year flood barriers: Benefits	100-year flood barriers: Project condition average annual damages	100-year flood barriers: Benefits
1	$ 69,800	$ 40,000	$29,800	$ 31,500	$38,300
2	136,600	127,000	9,600	77,000	59,600
3	118,000	70,000	48,000	47,500	70,500
4	548,100	458,800	89,300	362,500	185,600
5	93,000	53,000	40,000	32,500	60,500
6	108,200	75,400	32,800	50,000	58,200
Total	1,073,700	824,200	249,500	601,000	472,700

removal of an estimated 8.6 acres of mature tree cover with associated long-term habitat losses. Increased first costs of this Reach 1 alternative (50-year) incorporating a levee around the park would be approximately $367,000. Periodic flooding of Lincoln Park, principally the golf course, results in the periodic loss of income to the city and expenses for cleanup of mulch and debris and repairs of golf course greens and grounds. Protecting the park from a 50-year flood would result in average annual benefits of about $6,000 and an incremental benefit-cost ratio of 0.24.

The 100-year flood barrier would be continuous along the river from the vicinity of Belmont Road and 17th Avenue South northward to the vicinity of 20th Avenue North and Mill Road in Reach 5. Another levee extending westward from Mill Road together with a closure structure across English Coulee would prevent backup of Red River floodwaters into Reach 6. A total of 19 driveway raises and 2 street intersection raises would be required with an extended Belmont Road raise. Vegetation and associated habitat losses along Belmont Road and other reaches would be similar to the 50-year plan effects. An estimated 41 homes, (2, 18, 11, and 10 in Reaches 1, 2, 3, and 5, respectively) would need to be removed. Only minor vegetative losses would be experienced in Reach 4 because this riverbank area is heavily developed with roads, railways, and utilities and largely devoid of appreciable tracts of ground cover. With average barrier heights ranging from 5.3 feet in Reach 4 to 16 feet in Reach 5, visual access to the river would be severely affected. An estimated 27 acres of land (including 11 acres for road raises and other facilities) would be converted to permanent flood damage reduction uses. The 100-year flood barriers at Grand Forks together with the existing levee at East Grand Forks would increase flood levels less than 0.2 foot over the existing condition 100-year flood level.

As for the 50-year Reach 1 flood barrier plan, a 100-year flood barrier (road raise and levee) around Lincoln Park would eliminate the need for raising Belmont Road. However, in contrast to increased 50-year plan first costs with this modification, a Reach 1 100-year flood barrier including protection of the park would result in a total savings in first costs of about $247,000. A levee around Lincoln Park would remove between 10 and

11 acres of mature overstory with related habitat losses but would negate the need for 19 driveway grade raises and the removal of 2 homes.

A comparison of incremental costs and benefits indicates benefit-cost ratios of 0.3 and 0.4 for the Belmont Road raise and Lincoln Park flood barrier proposals, respectively.

A comparison of economic data including 100-year benefit-cost ratios for the individual Reaches 1 through 5 is given in table A-2 of Attachment A.

The considered standard project flood level barrier (average height of 8.2 feet in Reach 1 to 21 feet in Reach 5) would require the removal of about 50 homes and numerous road and building access closure structures as shown on figure 5. Required road raises along Belmont Road would require removal of four homes to accommodate intersecting street ramps. All boulevard trees along the raised road would be lost. Required closures along U.S. 81 (north and south) and U.S. Highway 2 (at I-29) would result in travel disruptions and isolate the community for at least a brief period. Major vegetative ground cover losses would generally be limited to the Central Park and Belmont Road areas. An estimated 104 acres of land would be required. The high flood barriers required would nearly eliminate view of the river in all areas. The alternative barrier incorporating a levee around Lincoln Park would reduce total first costs to about $3.3 million.

Diversion Channel

The diversion channel would reduce flood damages at both Grand Forks and East Grand Forks but only with extensive downstream main stem levees and channel works. With these additional measures, this alternative could provide an estimated total 100-year flood damage reduction benefit to Grand Forks and East Grand Forks of about $1,402,000. With water retained in the diversion channel during non-flood periods, the channel could possibly also serve as supplementary water supply and water body for open water

recreation uses. With allowances for required storage, the channel would also serve as an outlet for urban stormwater drainage from contributing areas primarily west of the urbanized Grand Forks area.

Conversely, the required channel excavation, related bridge, and other works would be grossly economically infeasible recognizing all previously described benefits. Construction of the 13-mile channel would require over 2,000 acres of land presently in agricultural use or being converted to urban uses. Total required bridge crossings would exceed 6 miles in length at a first cost in excess of $71 million. English Coulee and other drainage systems would require extensive modifications. Major channel clearing, widening, and deepening measures along the river downstream of the diversion would remove all river corridor forest cover and related habitat for several miles downstream.

An alternative 11-mile floodwater diversion channel around East Grand Forks would require the same downstream channel measures together with extensive control and diversion works at its junction with the Red Lake River. Required bridge crossings would be somewhat reduced, with three major highway crossings (U.S. Highway 2, State Highway 220) and three county highway crossings (County Highways 17, 19, and 64), plus crossings of local routes and two railroad tracks. Habitat losses would be considerably greater with the added permanent disruption of the Red Lake River corridor in the area of the diversion channel crossing.

Reservoir Storage

A recent unpublished study indicates that a considered upper Red Lake River reservoir would decrease flood peaks 1 foot and decrease average annual flood damages $250,000 at Grand Forks-East Grand Forks. Current studies of authorized projects on the Wild Rice and Sheyenne Rivers indicate additional stage reductions of 0.5 foot from each reservoir and average annual damage reductions of $90,000 and $100,000, respectively. However, the Upper Red Lake Reservoir is not considered probable in the near future because it was not economically feasible, and operational storage on the Wild Rice and Sheyenne Rivers is not expected for several years.

No significant adverse or beneficial environmental impacts on the study area are expected from these measures. Related effects in the considered reservoir areas have been assessed separately in studies of those reservoirs.

Channel Modifications

Major channel modifications alone through the Grand Forks-East Grand Forks area would have significant adverse environmental impacts. The required channel would require removal of most forest cover along the river corridor with associated small mammal and bird habitat and aesthetic losses. Extensive developed parkland in both communities would be a locational problem and further reduce wildlife habitat. Creation of the two channel cutoffs would involve the outright purchase of adjoining Minnesota land or a mutually agreeable trade. The considered cutoff near Lincoln Park (see figure 3) would benefit Lincoln Park with the possible addition of about 20 acres if legal and institutional restraints were resolved. The considered channel modifications would be considered further in stage 3 studies based on detailed economic, topographic, and hydraulic data.

Required raising of the Demers Avenue bridge by about 8 feet to pass the 100-year flood flow would result in either steep grade transitions at each end along with the loss of adjoining commercial property or more gradual transitions but with much greater adjacent property losses.

EVALUATION OF ALTERNATIVES

All of the alternatives were evaluated on the basis of satisfying the formulation and evaluation criteria listed earlier. Principal plan impacts were analyzed in relation to these criteria as discussed in the following paragraphs.

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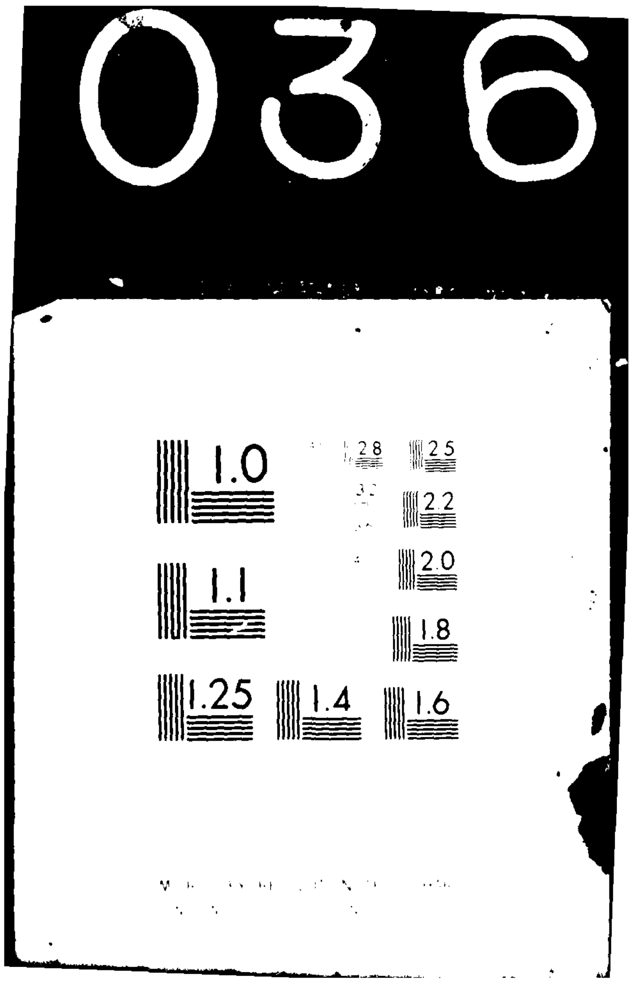
036
1.0
2.8
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

NONSTRUCTURAL ALTERNATIVES

Of the nonstructural alternatives considered, only permanent evacuation of the floodplain and emergency flood fight activities would provide an appreciable degree of flood damage reduction for the entire flood-prone area. Flood proofing measures, while not a total area solution, would reduce flood damages in selected areas of flood damage-prone development. Flood warning and forecasting alone would not reduce flood losses nor enhance area environmental qualities, but would serve as an invaluable complement to other measures to achieve a total plan. Similarly, flood insurance and floodplain regulations reduce economic losses to future floodplain development, but alone cannot protect existing development. Floodplain management measures such as zoning and subdivision regulations would aid in protecting biologically sensitive wetland areas from future unwise development. Thus, these existing measures will serve as effective partial "tools" for comprehensive floodplain management at Grand Forks.

Emergency flood barriers at Grand Forks would reduce flood damages up to about the 50-year flood level. For forecasted stages beyond this level, threatened areas would be evacuated temporarily. Total benefits attributable to these measures are estimated at about $305,000. A comparison of average annual benefits of $305,000 with associated annual costs of about $262,000 indicates a favorable benefit-cost ratio of about 1.2.

Although effective against flooding, permanent evaucation of the Grand Forks floodplain would result in a major upheaval of the city's economic and social system. Although this plan would substantially increase open-space areas, the city would oppose it for reasons of economic loss, local financial incapability, and adverse property and population displacement. Local residents could also expect to oppose a plan adversely affecting their economic and social condition. Thus, a permanent total evacuation plan is considered economically infeasible and socially unacceptable in solving the recurring flood problem at Grand Forks.

Flood proofing of suitable structures could reduce damages in most areas of Grand Forks but only at greater individual expense and inconvenience. Reduction of economic flood losses to individual properties would not relieve the periodic worry or anxiety associated with major flooding nor reduce the real threat to public health and safety. Local residents could be expected to oppose an enforced plan requiring major modifications to river-oriented walkouts and other improvements adversely affecting property aesthetic values. Flood-proofing regulations recently enacted by the city will be effective for future new development but do little for present structures. Only in selected areas of Reach 6 and the Olson and Elmwood Drive areas of Reach 1 does flood proofing appear effective on a broader scale for scattered clusters of residences and business development.

COMBINED NONSTRUCTURAL ALTERNATIVES

Of the nonstructural alternatives, none alone would meet area flood damage reduction needs. Combinations of these measures were then considered. Flood warning and forecasting services along with the current flood insurance program and floodplain regulations require no real addition in capital outlay but would do little to reduce potential losses to present development. Emergency flood fight activities, including the use of temporary barriers up to the 50-year flood level, could reduce flood damages in the area. A combined evacuation-flood proofing plan would reduce the adverse dislocation and financial consequences but still only at total costs greatly exceeding economic justification and local financial capability. Thus, for Grand Forks, future stage 3 studies of nonstructural alternatives should consider only emergency flood fight activities and flood proofing of selected concentrations of damage-prone property in Reach 1 (east of Belmont Road) and Reach 6 (Boyd Drive between 6th and 11th Avenues, Shakespeare Road, and near the mouth of the English Coulee).

STRUCTURAL ALTERNATIVES

Structural measures including floodwalls, levees, road raises, and/or various combinations, together with necessary interior drainage

measures, would provide a technically feasible means of reducing flood damages. All reaches could be individually protected at the 50-year flood level. For a 100-year level of flood damage reduction, Reaches 1 (part), 2, 5, and 6 could be practically protected. A combined barrier plan would probably be required for Reaches 3 and 4.

Economic feasibility based on an analysis of present condition flood damages and related benefits is indicated only for Reach 2 at the 50-year flood level as indicated by a 1.09 benefit-cost ratio (see table A-2, Attachment A). A 50-year level of flood damage reduction for Reaches 3 and 4 may be economically feasible recognizing benefits attributable to to future growth. Similarly, and if further study indicates a suitable 100-year flood barrier tie-in to high ground at Minnesota Avenue, a 100-year level of structural protection may be economically feasible for Reach 4 with the inclusion of benefits attributable to reduced damages to future development.

Economic feasibility for Reach 1 measures incorporating a raise of Belmont Road is clearly lacking for both the 50- and 100-year flood levels as indicated by respective benefit-cost ratios of 0.59 and 0.37 (table A-2). Alternate 50-year flood damage reduction measures incorporating a road raise and levee around Lincoln Park would increase total Reach 1 first costs by about 50 percent with a resultant benefit-cost ratio of about 0.4. Conversely, these same alternative Reach 1 measures for the 100-year flood level would reduce total first costs by about 28 percent with a resultant benefit-cost ratio of about 0.5.

A standard project flood level of protection for the entire flood-prone area could be provided only with substantial modifications of existing transportation routes; relocation of over 50 homes; impaired property use with numerous driveway raises along Belmont Road and 47th Avenue South; and the major loss of trees along Belmont Road, in the park areas, and on residential property. However, this level of protection would not be economically feasible as indicated by a benefit-cost ratio of about 0.2.

As previously discussed, a diversion channel around Grand Forks would be both technically and economically infeasible. It would probably be locally unacceptable because of high local costs ($2.5 million total local first costs) and extensive land requirements. Thus, this alternative is not considered further either alone or in combination with any other measure. Similarly a diversion of Red River flood flows around East Grand Forks is considered to be physically impractical, economically infeasible, and excessively environmentally disruptive. However, a diversion of Red Lake River flood flows around East Grand Forks via the Grand Marais Coulee drainage course may have considerable merit and should be investigated in stage 3 studies.

Upstream reservoir storage is physically capable of meeting about one-half of the area's flood damage reduction needs. However, the demonstrated infeasibility of storage on the Red Lake River and uncertain timing of authorized Wild Rice and Sheyenne improvements do not make this a viable solution for at least the next 10 to 15 years. If and when ultimately realized, these latter two improvements in concert with main stem flood barriers at Grand Forks could reduce damages from the lower frequency floods. However, at this time, upstream reservoir storage is not considered an effective total plan for flood damage reduction at Grand Forks.

Channel modifications alone as described would be economically unjustified and impractical in terms of the required 1,000- to 1,200-foot channel width and related bridge modifications. This alternative would also probably be vigorously opposed by both communities because it would eliminate the existing riverine community focus and it has unfavorable local financial requirements. Thus, channel modifications alone are not considered further as a viable measure for flood damage reduction. However, a combination of selected channel improvement measures together with required bridge modifications and flood barriers may be feasible and should be further investigated in detail in stage 3 studies.

CONTRIBUTION OF ALTERNATIVES TO NATIONAL OBJECTIVES

The selected plan for effective and permanent floodplain management in Grand Forks must satisfy the specific objectives for the study area listed earlier and provide positive contributions to the NED, EQ, regional development, and social well-being objectives. Separate plans -- one optimizing economic efficiency, the other emphasizing environmental quality -- were developed. Through a series of trade-offs among public preferences expressed at meetings of 18 January and 23 March 1978 and beneficial-adverse plan impacts (see table 4), the plan which contributed most to the local and national planning objectives was developed in accordance with the system of accounts procedure established by the U.S. Water Resources Council.

NATIONAL ECONOMIC DEVELOPMENT (NED) PLAN

The NED plan must, from the national point of view, represent the maximum return on the investment of economic resources including capital, labor, and irreplaceable resources required for construction.

Of all the alternatives considered, a plan including emergency flood fight and disaster relief activities is the only total plan that would be economically feasible. The NED plan would specifically provide for the raising and strengthening of emergency barriers up to the 50-year flood level along existing alignments in Reaches 3 and 5, a 1,000-foot temporary earthen barrier either along or alongside 3rd Street in Reach 4 between Division and Minnesota Avenues, a temporary earthen barrier along Belmont Road (Reach 1) between 13th and 17th Avenues South, and an 800-foot temporary earthen barrier along Alpha Avenue between North 4th and 6th Streets in Reach 5. When imminent stages exceeding the 50-year flood level are forecast, all residents would be evacuated from the flood-prone areas. Removal of building contents to either higher flood elevations or outside the flood-prone areas would be left to individual choice as time and transport facilities would permit. The NED plan would also include nonstructural measures currently in effect such as flood forecasting, flood insurance, and zoning and subdivision regulations.

ENVIRONMENTAL QUALITY (EQ) PLAN

The EQ flood damage reduction plan for Grand Forks is the plan that would satisfy the area's floodplain management objective while enhancing environmental quality through the preservation or enhancement of important natural and cultural resources and ecological systems. The EQ plan would also minimize adverse effects on environmental quality. The selected environmental quality alternative was the alternative that was initially least environmentally disruptive to the existing project area setting on the basis of a preliminary assessment of area environmental conditions and expected plan impacts.

From the analyses of alternatives considered further for principally flood damage reduction, it was determined that the EQ plan would also include the emergency flood fight and disaster relief activities measures as outlined for the NED plan. Construction of the temporary barriers along existing flood barrier alignments and city streets is considered to be the least environmentally disruptive since these areas are either presently paved or otherwise devoid of native vegetation. The EQ plan would also incorporate other floodplain management measures such as flood insurance and zoning and subdivision regulations to restrict unwise future damage-prone development and reduce the future flood damage potential. Also included would be aesthetic treatment measures such as tree and shrub plantings to minimize the visual impact of any emergency barriers left in place.

PLAN SELECTION

Selecting the most technically practical, economically efficient, and locally desirable alternative for further investigation in stage 3 studies involved the comparison of alternatives which satisfied the established local, regional, and national planning objectives and formulation and evaluation criteria. Of the measures considered, a plan incorporating emergency flood fight and disaster relief activities, together with related aesthetic measures and the continuance and expansion of

local flood forecasting, flood insurance, and floodplain management programs is considered in balance to be the best plan for the total study area that should be investigated in stage 3 studies.

Other solutions that would also aid in meeting the city's floodplain management needs and which should be further investigated in stage 3 studies include upgrading of the level of protection provided by the existing Lincoln Park project, a diversion of Red Lake River flood flows around East Grand Forks via the Grand Marais Coulee channel, a control structure with attendant flood barriers across English Coulee north of 27th Avenue North to prevent backup of Red River flood flows, flood barriers to provide a 100-year level of protection to combined Reaches 3 and 4 or Reach 4 alone, and flood-proofing measures in the southern portion of Reach 1 and central (U.S. Highway 2 area) and northern (near the mouth of the English Coulee) portions of Reach 6.

PLAN IMPLEMENTATION

Detailed stage 3 studies would be made by the Corps of Engineers at no cost to the city of Grand Forks. Assuming that these stage 3 detailed feasibility studies confirm the above conclusions or produce a better overall plan, the stage 3 study report for floodplain management would be forwarded through the Secretary of the Army to Congress for authorization of detailed planning and engineering studies. If authorized and funded by the Congress, these studies would also be made by the Corps of Engineers at no cost to the city.

If these postauthorization studies either confirm the earlier recommended plan or indicate some other preferable course of action, after further congressional review, approval, and funding, detailed engineering designs and specifications would be made as required. Upon completion of this work, the project would be advertised for bids with subsequent award of a construction contract to the qualified low bidder.

The U.S. Government would generally assume the cost of any flood control features and a maximum of 3 percent of the total construction cost for aesthetic treatment measures. Local interests would provide at no cost

to the U.S. Government all lands, easements, and rights-of-way required for construction and subsequent operation and maintenance. They would also agree to operate and maintain the project at their own expense and in a manner acceptable to the U.S. Government. The local project sponsor would likewise agree to other provisions of local cooperation concentering floodplain management, intrusions onto project works, and any other cost-sharing arrangements that may be deemed advisable.

RECOMMENDATION

On the basis of this stage 2 study of floodplain management needs, I recommend that detailed stage 3 studies be made of the following course of action:

- An emergency flood fight and disaster relief plan that the city of Grand Forks could implement before, during, and after a major flood.

Insofar as the stage 2 plan formulation studies have indicated possible merit of other alternatives pending completion of additional economic studies and topographic surveys and insofar as the cities of Grand Forks and East Grand Forks desire a permanent means of flood damage reduction, I recommend the following additional stage 3 investigations:

- A feasibility scope analysis of the diversion of Red Lake River flood flows around East Grand Forks via the Grand Marais Coulee channel.

- An investigation of the feasibility of a control structure with attendant flood barriers across English Coulee to prevent damaging backup of Red River flood flows.

- Feasibility studies to ascertain the advisability of upgrading the existing federally-constructed Lincoln Park (Reach 2) project to provide a higher level of protection.

- Additional study to ascertain the advisability of flood-proofing measures for flood-prone structures along the Olson and Elmwood Drive areas of Reach 1, along Boyd Drive between 6th and 11th Avenues North, and the commercial areas both north and south of U.S. Highway 2 in Reach 6.

- Further study to determine, in view of the potential catastrophic losses in the central business district and preliminary indications of possible economic feasibility, the advisability of providing a protective flood barrier with related works for combined Reaches 3 and 4 or Reach 4 alone.

- Additional topographic surveys as required and study of potential future damage growth in support of the foregoing recommendations.

ATTACHMENT A

SUMMARY OF COSTS AND BENEFITS

Table A-1 - Cost estimate summary--flood barrier alternative[1]

ITEM		REACH 1 50-Yr	REACH 1 100-Yr	REACH 2 50-Yr	REACH 2 100-Yr	REACH 3 50-Yr	REACH 3 100-Yr	REACH 4 50-Yr	REACH 4 100-Yr	REACH 5 50-Yr	REACH 5 100-Yr	TOTAL ALL REACHES 50-Yr	TOTAL ALL REACHES 100-Yr	TOTAL ALL REACHES SPF
Levees		0	0	56,400	104,500	70,400	152,400	0	0	135,800	187,600	262,600	444,500	1,975,000
Floodwalls		0	289,400	30,000	905,800	0	0	613,700	1,836,400	1,185,400	1,762,000	1,829,100	4,793,600	37,372,000
Road Raises		109,000	205,000	0	0	0	0	0	60,000	75,000	71,000	184,000	336,000	1,943,000
Road and Driveway Ramps		49,000	299,000	10,000	0	19,000	23,000	0	0	129,000	203,000	207,000	525,000	2,845,000
Closure Structures		0	0	0	52,000	200,000	300,000	278,500	593,500	260,000	350,000	738,500	1,295,500	4,246,000
Interior Drainage		262,000	319,000	10,000	60,000	625,000	771,000	527,000	1,188,000	1,185,000	1,232,000	2,609,000	3,570,000	7,018,000
Relocations		0	2,400	5,000	0	0	0	6,200	12,800	43,800	43,800	55,000	59,000	200,000
Modifications		0	12,500	0	5,400	0	0	12,500	12,500	0	0	12,500	30,400	100,000
Control Structures		0	0	0	0	0	0	0	0	0	0	0	0	127,000
House and Other Purchases		0	125,000	0	1,125,000	0	687,500	50,000	160,000	656,200	656,200	706,200	2,753,700	3,231,000
Lands and Rights-Of-Way		16,900	30,000	2,000	9,600	20,500	35,600	15,000	52,200	99,600	113,600	154,000	241,000	408,000
Total Construction Cost		436,900	1,282,300	113,400	2,262,300	934,900	1,969,500	1,502,900	3,855,400	3,769,800	4,619,200	6,757,900	14,048,700	59,465,000
Total Construction Cost[2]	- Federal	420,000	1,112,400	106,400	1,122,300	914,400	1,246,400	1,419,200	3,677,900	2,970,200	3,805,600	5,830,200	10,964,600	55,526,000
	Non-Federal	16,900	169,900	7,000	1,140,000	20,500	723,100	83,700	237,500	799,600	813,600	927,700	3,084,100	3,939,000
E,D,S & A	- Federal	63,000	166,600	16,600	168,700	137,000	187,000	212,800	551,700	445,500	570,800	874,900	1,644,800	8,329,000
	Non-Federal	2,500	25,100	1,000	171,000	3,100	108,500	12,300	35,900	119,700	122,000	138,600	462,500	591,000
Total First Costs	- Federal	483,000	1,279,000	123,000	1,291,000	1,051,400	1,433,400	1,632,000	4,229,600	3,415,700	4,376,400	6,705,100	12,609,400	63,855,000
	Non-Federal	19,400	195,000	8,000	1,311,000	23,600	831,600	96,000	273,400	919,300	935,600	1,066,300	3,546,600	4,529,000
		502,400	1,474,000	131,000	2,602,000	1,075,000	2,265,000	1,728,000	4,503,000	4,335,000	5,312,000	7,771,400	16,156,000	68,384,000

1 Includes 25 percent for contingencies.

2 Not including engineering, design, supervision and administration.

Table A-2 - Comparison of annual costs and benefits--flood barrier alternative

	REACH 1		REACH 2		REACH 3		REACH 4		REACH 5	
	50-Yr	100-Yr	50-Yr	100-Yr	50-Yr	100-Yr	50-Yr	100-Yr	50-Yr	100-Yr
Federal Annual Costs	$32,100	$84,900	$8,200	$ 85,700	$ 69,800	$ 95,100	$108,300	$280,700	$226,700	$290,400
Non-Federal Annual Costs	2,800	17,100	600	88,500	3,900	58,700	11,900	33,200	72,700	77,600
Total Annual Costs	34,900	102,000	8,800	174,200	73,700	153,800	120,200	313,900	299,400	368,000
Total Annual Benefits	20,800	38,300	9,600	59,600	48,000	70,500	89,300	185,600	40,000	60,500
Benefit-Cost Ratio	0.59	.37	1.09	.34	.65	.45	.74	.59	.13	0.16
Remaining Flood Damages	40,000	31,500	127,000	77,000	70,000	47,500	458,800	362,500	53,000	32,500
% Flood Damage Reduction	30	55	7	44	41	60	16	34	43	65
Max. Net Benefits	-14,100	-63,700	800	-114,600	-25,700	-83,300	-30,900	-128,300	-259,400	-307,500

Table A-3 - Summary of annual costs--flood barrier alternative--50-year plan

	REACH 1	REACH 2	REACH 3	REACH 4	REACH 5	TOTAL ALL REACHES
Federal First Cost	$483,000	$123,000	$1,051,400	$1,632,000	$3,415,700	$6,705,100
Non-Federal First Cost	19,400	8,000	23,600	96,000	919,300	1,066,300
Federal Annual Costs						
Interest and amort. (.06636)	32,100	8,200	69,800	108,200	226,700	4,451,000
Total Federal Annual Costs	32,100	8,200	69,800	108,300	226,700	4,451,000
Non-Federal Annual Costs						
Interest and amort.	1,300	500	1,600	6,400	6,100	70,800
O, M & R Int. drain.	800	0	1,900	1,000	3,900	7,600
Levees, etc.	700	100	400	4,500	7,800	13,500
Total Non-Federal Annual Cost	2,800	600	3,900	11,900	72,700	91,900
Total Annual Costs	34,900	8,800	73,700	120,200	299,400	537,000

Table A-4 - Summary of annual costs--flood barrier alternative--100-year plan

	REACH 1	REACH 2	REACH 3	REACH 4	REACH 5	TOTAL ALL REACHES
Federal First Costs	$1,279,000	$1,291,000	$1,433,400	$4,229,600	$4,376,400	$12,609,400
Non-Federal First Cost	195,000	1,311,000	831,600	273,400	935,600	3,546,600
Federal Annual Cost						
Interest and amort. (.06636)	84,900	85,700	95,100	280,700	290,400	836,800
Total Federal Annual Costs	84,900	85,700	95,100	280,700	290,400	836,800
Non-Federal Annual Cost						
Interest and amort.	11,900	87,000	55,200	18,100	62,100	235,300
O,M& R Int. Drain	1,000	200	2,800	4,200	4,400	12,600
Levees	3,200	1,300	700	10,900	11,100	27,200
Total Non-Federal Annual Costs	17,100	88,500	58,700	33,200	77,600	275,100
Total Annual Costs	102,000	174,200	153,800	313,900	368,000	1,111,900

Table A-5 - Summary of annual costs--flood barrier alternative

	SPF PLAN TOTAL ALL REACHES
Federal First Cost	$ 63,855,000
Non-Federal First Cost	4,529,000
Federal Annual Costs	
Interest and amort. (.06636)	4,237,400
Total Federal Annual Costs	4,237,400
Non-Federal Annual Costs	
Interest and amort. (.06636)	300,500
O, M & R Int. drain.	27,300
Levees, etc.	73,100
Total Non-Federal Annual Costs	400,900
Total Annual Costs	4,638,300

Table A-6 - Summary of average annual damages and benefits(1)

Reach	Average annual damages	Average annual benefits: 50-year level of protection	100-year level of protection	Standard project flood level of protection
1	$69,800	$20,800	$38,300	$64,800
2	136,600	9,600	59,600	125,400
3	118,000	48,000	70,500	108,000
4	548,100	89,300	185,600	485,600
5	93,000	40,000	60,500	88,000
6	108,200	32,800	58,200	94,900
Total (all reaches)	1,073,700	249,500	472,700	966,700

(1) For present condition development only.

ATTACHMENT B

BIBLIOGRAPHY

BIBLIOGRAPHY

Agencies Contacted:

U.S. Army Corps of Engineers, St. Paul District

U.S. Soil Conservation Service, Grand Forks

U.S. Department of Commerce, National Weather Service

U.S. Geological Survey, Grand Forks

North Dakota State Water Commission

Grand Forks County Water Management and Control Board

Grand Forks City Engineer

Grand Forks City Planning Office

Grand Forks Community Development and Housing Authority

Grand Forks Parks and Recreation Department

Organizations and Individuals:

KBM, Inc., Grand Forks

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STAGE 2 URBAN DRAINAGE STUDY

AT GRAND FORKS, NORTH DAKOTA

PURPOSE

This preliminary report provides information for formulating a master drainage plan for future urban development in Grand Forks, North Dakota. The report presents the first iteration of alternatives for urban drainage and is limited to a preliminary hydrologic analysis. Problems and needs are identified and possible alternatives to meet urban runoff needs are discussed. The findings of the report will be used as a basis for discussion with agencies, organizations, and individuals concerned with or affected by these problems. The results of the discussions and comments will be evaluated and considered in defining the direction of further studies to be undertaken in stage 3.

PROBLEMS AND NEEDS

The urban drainage problems and needs in the Grand Forks study area can be classified into the following major categories: (1) future growth and development, (2) operation and maintenance of existing urban drainage systems, (3) lack of a master urban drainage plan, and (4) technical problems.

FUTURE GROWTH PROBLEMS

Growth contributes to the economic well-being of the residents of the city and surrounding rural areas and, to a lesser extent, the Nation. However, problems evolve that are generally related to the ways of managing growth, development patterns that evolve, and other effects. These problems may not be directly related to urban drainage, but they affect water resource management plans such as urban drainage. A water resource management plan considering urban drainage problems and needs can contribute to alleviating or reducing the impacts of growth related problems.

Specific growth related problems identified by the city of Grand Forks are:

a. Poor mix of industrial and residential land uses.

b. Loss of activity centers.

c. Uncoordinated, congested commercial areas.

d. Loss of public transit potential in new areas.

e. Decline of older neighborhoods in favor of new areas.

f. Longer travel distances.

g. Higher costs of municipal services.

The city wishes to overcome these problems by controlling growth. The city's development goal is the creation of a well planned, compact urban area. Adoption of workable urban drainage policies and development of a coordinated drainage management plan can benefit urban water resource and related activities consistent with the city development goal.

A growth problem specifically related to development of an urban drainage management plan is forecasting growth within the planning area. Without knowledge of the type of development that will occur and the timing of the growth, it is difficult to develop a meaningful and valid drainage management plan. At the same time, it is unrealistic to assume that these forecasts can be made with certainty. It is therefore necessary to make certain simplifying assumptions and, on the basis of available data, determine the most probable future. To be valuable, a long-term plan must provide a framework for the future but, to be practical, it must also be adaptable to future growth conditions.

EXISTING AND FUTURE URBAN DRAINAGE PROBLEMS AND NEEDS

Existing Urban Drainage

Over 4 square miles of Grand Forks is currently served by storm sewers. Approximately 1.4 square miles surrounding the central business district is served by combined sewers (see figure 1). The city experiences periodic problems of combined sewer overflows and sewer backups causing basement flooding during periods of flooding and heavy rain. The city has initiated a plan to separate the stormwater and sanitary sewer system in this area. In general, the combined sewers will be slip lined and converted to sanitary sewers and new storm sewers will be constructed. Some large combined sewers will be used as storm sewers and new sanitary sewers will be constructed in these instances.

The separation plan has been divided into four phases (see figure 1). Phase I, which includes the downtown area, has already begun and is scheduled for completion in 1979. Starting dates for the other phases have not yet been established.

This study assumes that the city has a viable plan for implementing the separation of combined sewers; therefore, the study will not address this problem.

Future Urban Drainage

In the unsewered portion of the city and the rural area out to the presently defined 2-mile zoning limit, a definite need for long-range master stormwater drainage plans exists. Development is expanding into this undeveloped area, especially south of the city. The momentum of urban development is steadily increasing and has consistently exceeded recent short-term projections. The city has adopted the Planned Unit Development concept which gives the city a mechanism for

guiding large-scale private development toward the overall development goals. However, without a public development plan that addresses issues such as urban drainage, city officials have indicated that they will have difficulty in taking full advantage of the opportunities of the Planned Unit Development concept. Specific examples of problem areas relating to urban drainage are:

a. Difficulties in using open-space requirements of Planned Unit Development for providing ponding areas and drainage courses for runoff.

b. Difficulties in providing guidance to private developers on how future drainage needs will be met.

c. Forgone opportunities to influence desired growth patterns by adopting plans for development of municipal services.

To achieve the city's goal and solve or avoid other specific problems, city officials have expressed a need for an overall stormwater management plan. Specific water resource problems that the plan should address are:

a. Overland flooding - Lack of definite drainage courses within the typical subdrainage area and flatness of terrain result in sheet flow over the entire area during periods of heavy runoff. Under these conditions virtually all man-made features are subject to damage. This natural condition has encouraged property owners to resort to land drainage practices which collect and accelerate runoff. This increases the potential for localized flooding problems in other areas and perpetuates the same types of practices.

b. Flooding on Red River of the North and English Coulee - Land drainage practices and intensified development of agricultural areas have resulted in increased runoff which has the potential for increasing the existing flood hazards along English Coulee and the Red River of the North. Urban drainage into these systems may compound the problem.

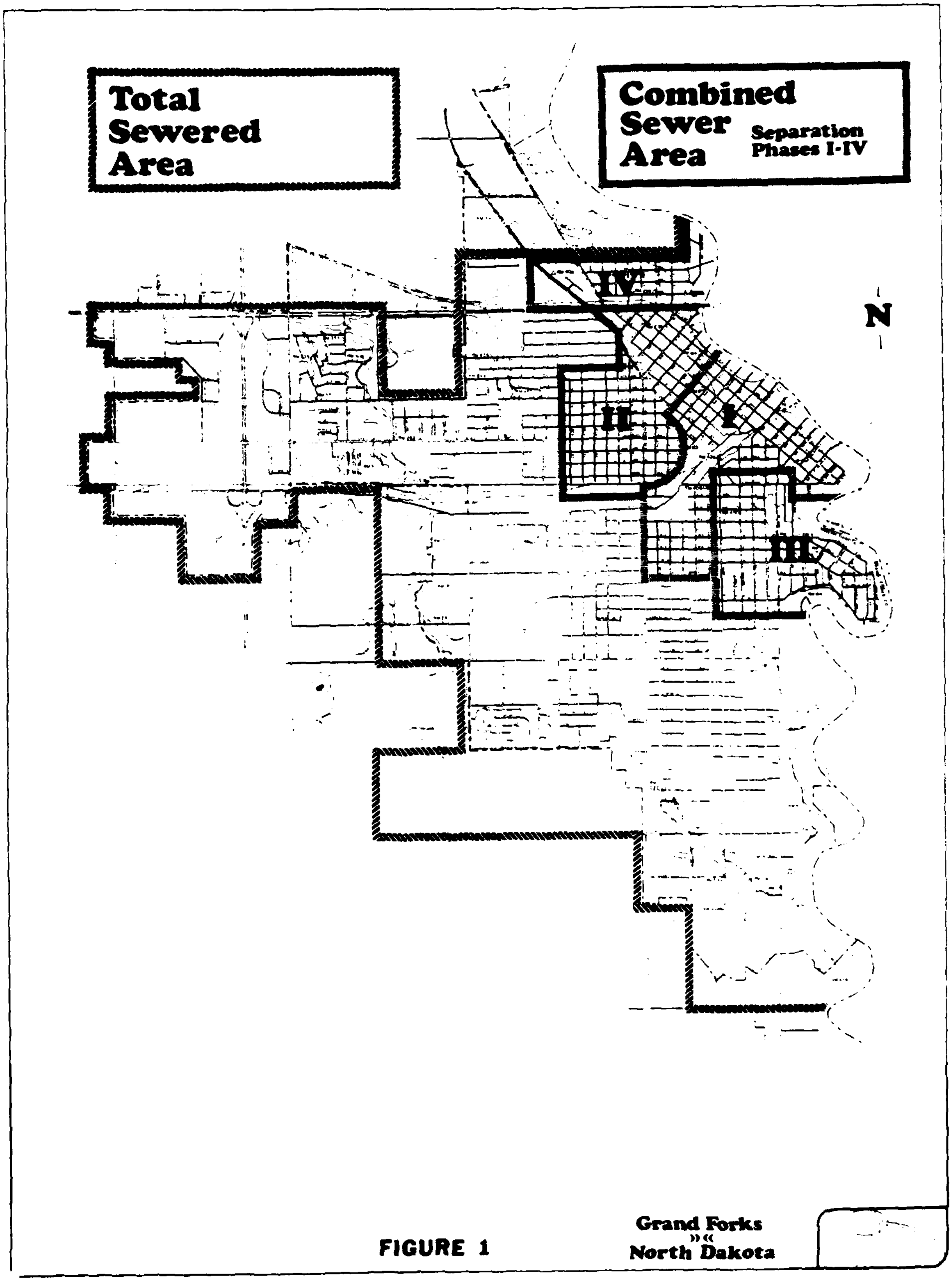

Total Sewered Area
Combined Sewer Area
Separation Phases I-IV
IV
II
I
III
N
Grand Forks
North Dakota

FIGURE 1

c. Erosion - As natural drainage patterns are changed and vegetative cover is reduced, runoff velocity will be increased. Without proper management techniques, soil erosion may be significantly increased.

d. Water quality - Soil erosion and pollutants from other nonpoint sources can result in poor quality stormwater runoff. Discharge of stormwater without treatment can cause significant water quality degradation in the receiving waters.

The benefit of developing an overall stormwater management plan is that, in the long term, it can lower the total cost of an urban drainage system. Studies have shown that proper long-range planning reduces capital costs an average of 15 percent. These cost savings are possible by allowing a community to take maximum advantage of incorporating natural features into a drainage system and to plan for development of other facilities before these features are altered or the opportunities are otherwise forgone. A good plan provides a long-range scheme of development that can minimize the need to replace or upgrade facilities due to premature obsolescence. Ideally, the plan includes a phased system of development that can serve the current needs and be adaptable to future needs at the minimum total cost. It allows new growth development to be planned that will move the city closer to achieving its goals rather than becoming obstacles to them.

TECHNICAL PROBLEMS

The investigation has identified the following technical problems which have either been encountered or are anticipated:

a. There is a lack of technical data available on existing facilities. Data on many of the hydraulic structures, for example, are either nonexistent or have been lost or destroyed.

b. The flat topography makes it difficult to distinguish drainage patterns or identify drainage areas. The relief is so slight in most areas that it is unobservable without survey instruments. It is not uncommon at a road intersection to find a conduit through each approach to the intersection. Thus, determining the direction of flow by observing the locations of conduits is not reliable. Local interests stated that in some instances the direction of flow of runoff depends upon wind direction.

c. The lack of relief within the study area limits the number of alternatives available and imposes certain limitations on those that are feasible.

d. Under existing conditions the agricultural land has excellent capacity for surface storage. However, the land is vulnerable to greatly increased runoff after urban development.

THE STUDY AREA

The limits defined for this urban drainage study are shown on figure 2. The study area includes all areas outside the sewered portion of the city and within the city's 2-mile limit of jurisdiction. The city's land use zoning jurisdiction extends to 2 miles beyond its existing city limits. Because of the rapid rate of development south of the city, the study area was extended southward an additional mile beyond the 2-mile zoning limit between the Red River of the North and Interstate 29. The study area is a 21,000-acre band of primarily agricultural land starting at the Red River of the North south of Grand Forks, encircling the city and meeting the Red River again north of the city. The study area is cut in the north-south direction by Interstate 29 and the Burlington Northern railroad tracks. It is cut in the east-west direction by Highway 2, Burlington Northern railroad tracks, Legal Drains 4 and 9, and the English Coulee floodway.

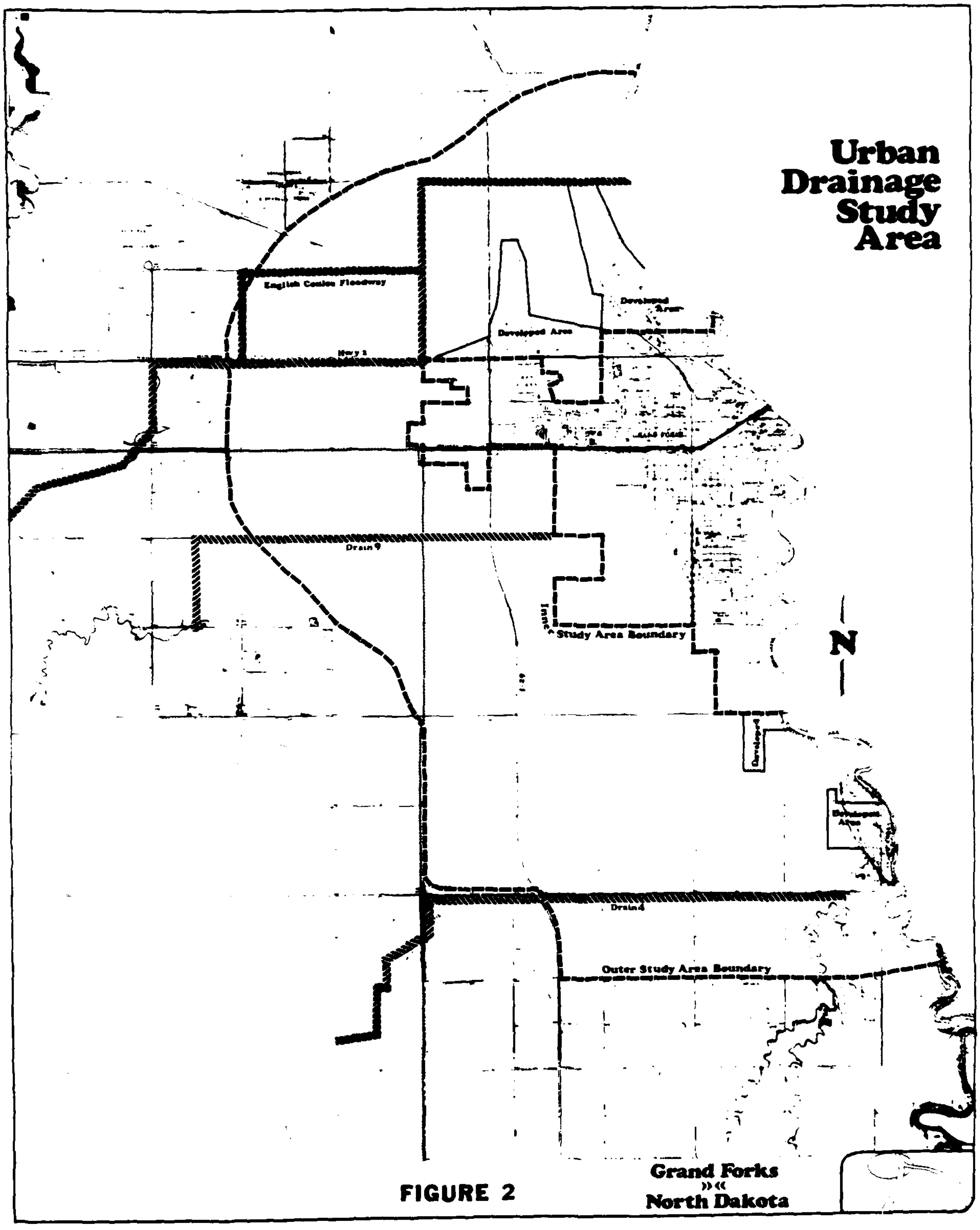

Urban
Drainage
Study
Area
English Coulee Floodway
Developed Area
Hwy 2
Drain 9
Study Area Boundary
N
Developed
Drain 4
Outer Study Area Boundary
Grand Forks
North Dakota

FIGURE 2

THE BASE CONDITION

Natural drainage in the study area is from southwest to northeast. A large portion of the rural land southwest of Grand Forks drains toward the city (see figure 3). The Cole Creek watershed south of the study area drains approximately 40 square miles of rural land. The drainage from the watershed that does not flow directly into Cole Creek is intercepted by Legal Drain 4 and then flows into Cole Creek and the Red River of the North. Legal Drain 4 has a capacity of about 450 cfs (cubic feet per second).

English Coulee and the English Coulee floodway are the two main drainage courses of the English Coulee watershed. The English Coulee watershed drains approximately 95 square miles of primarily rural agricultural land. Legal Drain 9 is a 5-mile improved portion of English Coulee southwest of the city. About 5 miles west of the study area, a diversion structure on English Coulee diverts flows in excess of 1,000 cfs into the English Coulee floodway which conveys up to 600 cfs of flow west and north of the city and into the Red River of the North near the confluence of English Coulee and the Red River. Flows in excess of 1,600 cfs from English Coulee watershed will exceed the capacity of the system.

The rural area has a slope of 2.0 to 2.5 feet per mile. Other than English Coulee, Belmont Coulee, Cole Creek, and a few small shallow potholes north of Highway 2 in subbasin area A (figure 4), few areas of natural relief exist in the study area.

Major areas of development in the study area are shown on figure 2. Other development is limited primarily to single residential units or small residential developments scattered throughout the study area.

Currently, drainage of stormwater is by overland flow and the existing system of road ditches. Because of the low density of development and the absorptive capacity of agricultural land, runoff from frequent storms creates no significant problems.

Estimated peak runoffs for each drainage area under existing conditions for 5- and 10-year frequency rainfalls are shown in tables 1 and 2, respectively. A more detailed description of drainage for the study area is given in the section titled "Existing Drainage Patterns."

Table 1 - Estimated peak runoff, 5-year frequency

Drainage area (1)	Area (acres)	Intensity (inches per hour)	Estimated peak flow: Existing condition (cfs)	Estimated peak flow: Future condition (cfs)
A	5,700	0.7	800	1,400
B	3,000	0.35	210	370
C_1	3,400	0.30	205	355
C_2	10,000	0.20	400	(2)
E	1,600	0.50	160	280
I	820	0.75	125	215
J	1,500	0.65	195	340
K	3,370	0.25	170	295
L	1,420	0.70	200	350
R	450	1.3	115	205

(1) See figure 4.
(2) Outside study area; not to be developed.

Table 2 - Estimated peak runoff, 10-year frequency

Drainage area	Area (acres)	Intensity (inches per hour)	Peak flow: Existing condition (cfs)	Peak flow: Future condition (cfs)
A	5,700	0.85	970	1,695
B	3,000	0.50	300	(1)
C_1	3,400	0.40	270	475
C_2	10,000	0.30	600	(1)
E	1,600	0.60	190	335
I	820	0.95	155	275
J	1,500	0.80	240	420
K	3,370	0.35	235	415
L	1,420	0.90	255	450
R	450	1.65	150	260

(1) Outside study area; not to be developed.

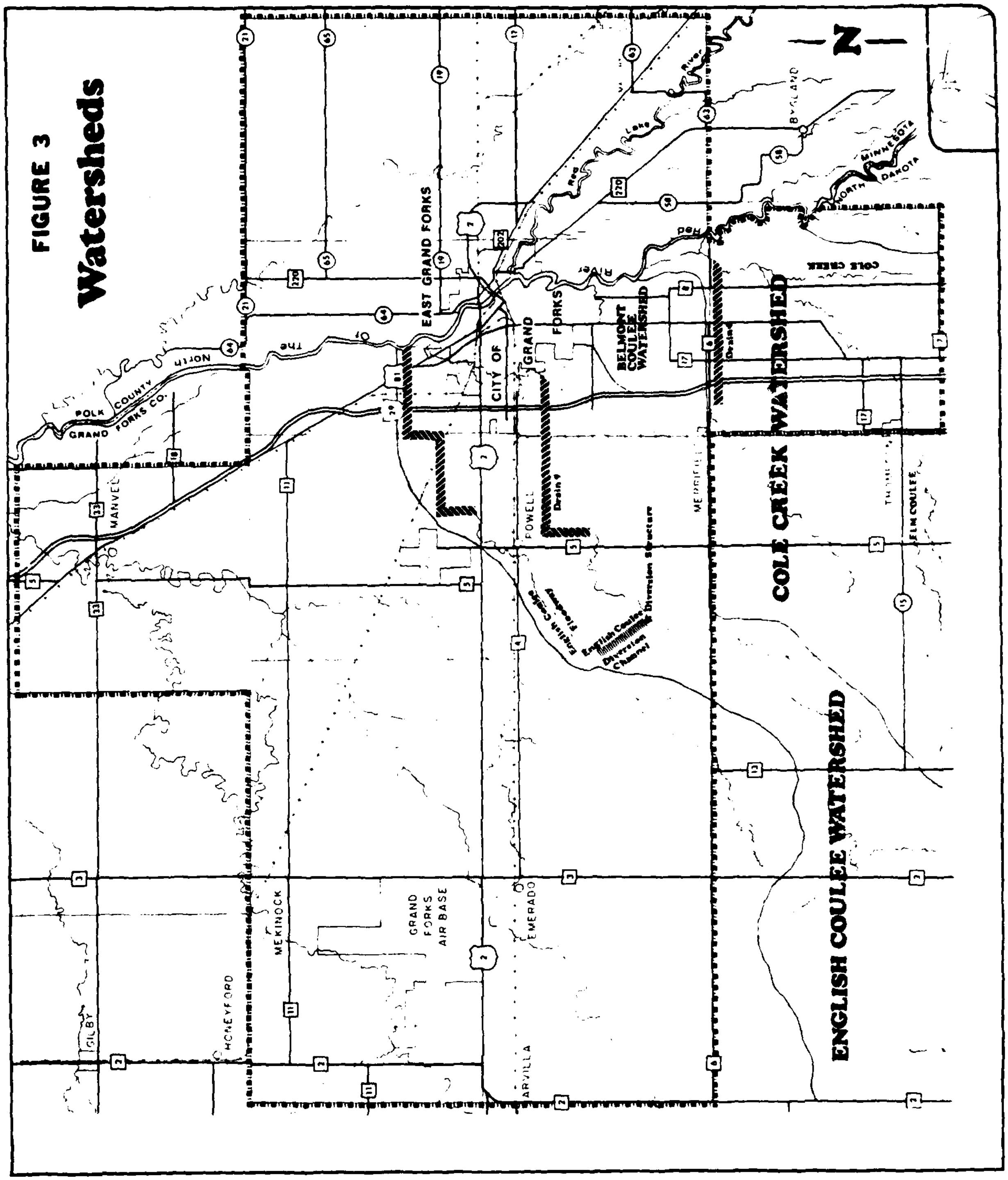


FIGURE 3
Watersheds

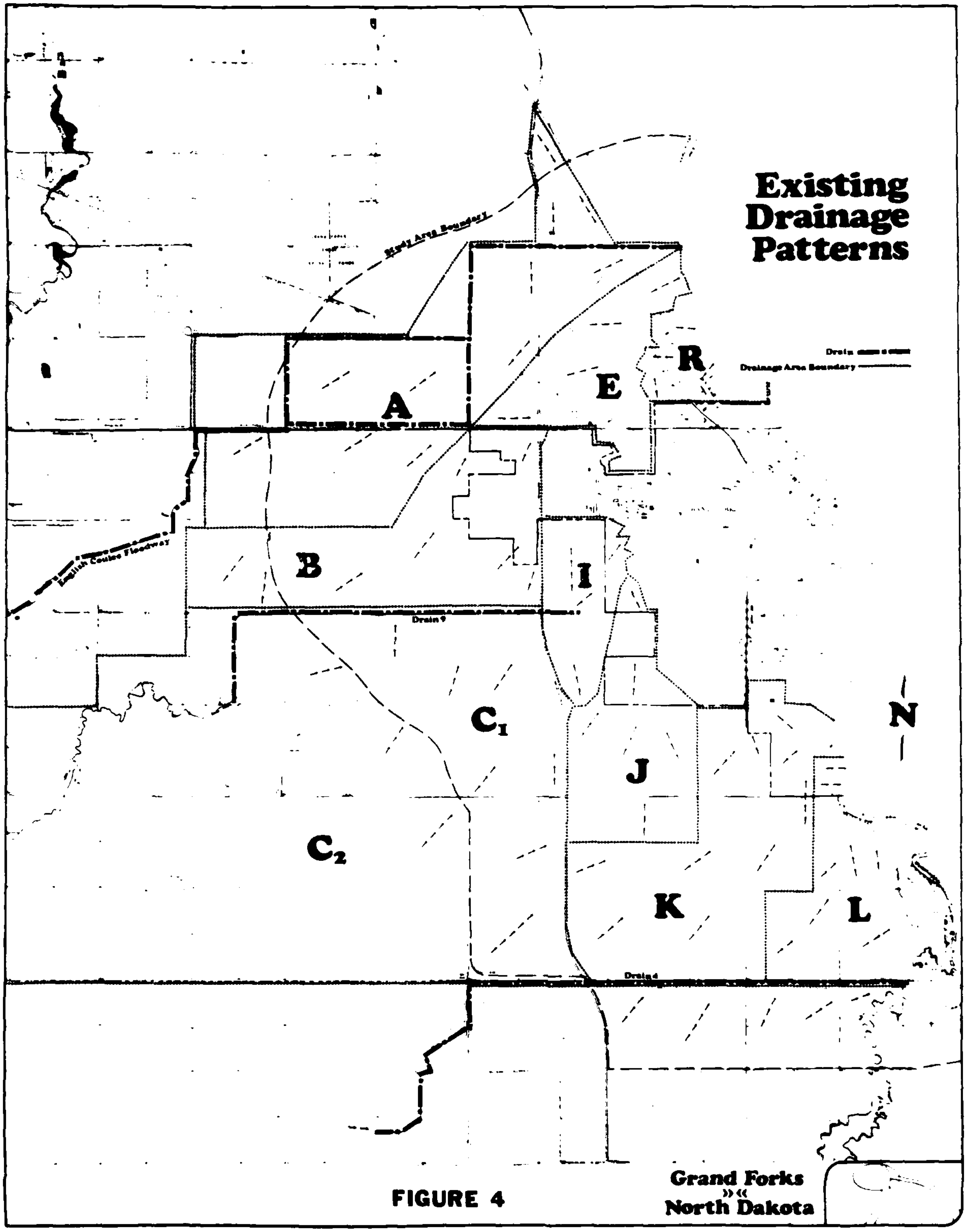

Existing
Drainage
Patterns
Drain
Drainage Area Boundary
Study Area Boundary
English Coulee Floodway
Drain 9
Drain 4
A
B
C1
C2
E
R
I
J
K
L
N
Grand Forks
North Dakota

FIGURE 4

PEAK RUNOFF METHODOLOGY

Many methods are available for relating runoff to rainfall. The rational method was selected primarily because it is widely accepted and is used by the city and its consultants. More complex methods did not seem justified for preliminary planning. Urban storm sewer systems are commonly designed for 5- to 25-year rainfall events. The city of Grand Forks desired that the primary system be designed for a 5-year rainfall event. For comparison, the 10-year rainfall event was also analyzed.

The rational formula is computed as $Q = CiA$ in which:

Q = Discharge rate in cfs.

C = Runoff coefficient representing the characteristics of the drainage area. A composite C value was computed for existing conditions (0.2) and for assumed future development conditions (0.35).

i = Average intensity of rainfall in inches per hour for a duration equal to the time of concentration, t, for a selected rainfall frequency. These values are obtained from standard intensity-duration-frequency relationships for the area (figure 5).

t = Time in minutes after the beginning of rainfall for runoff to peak at the point under consideration. This depends on the size, shape, and slope of the drainage area.

A = Size of the drainage area in acres.

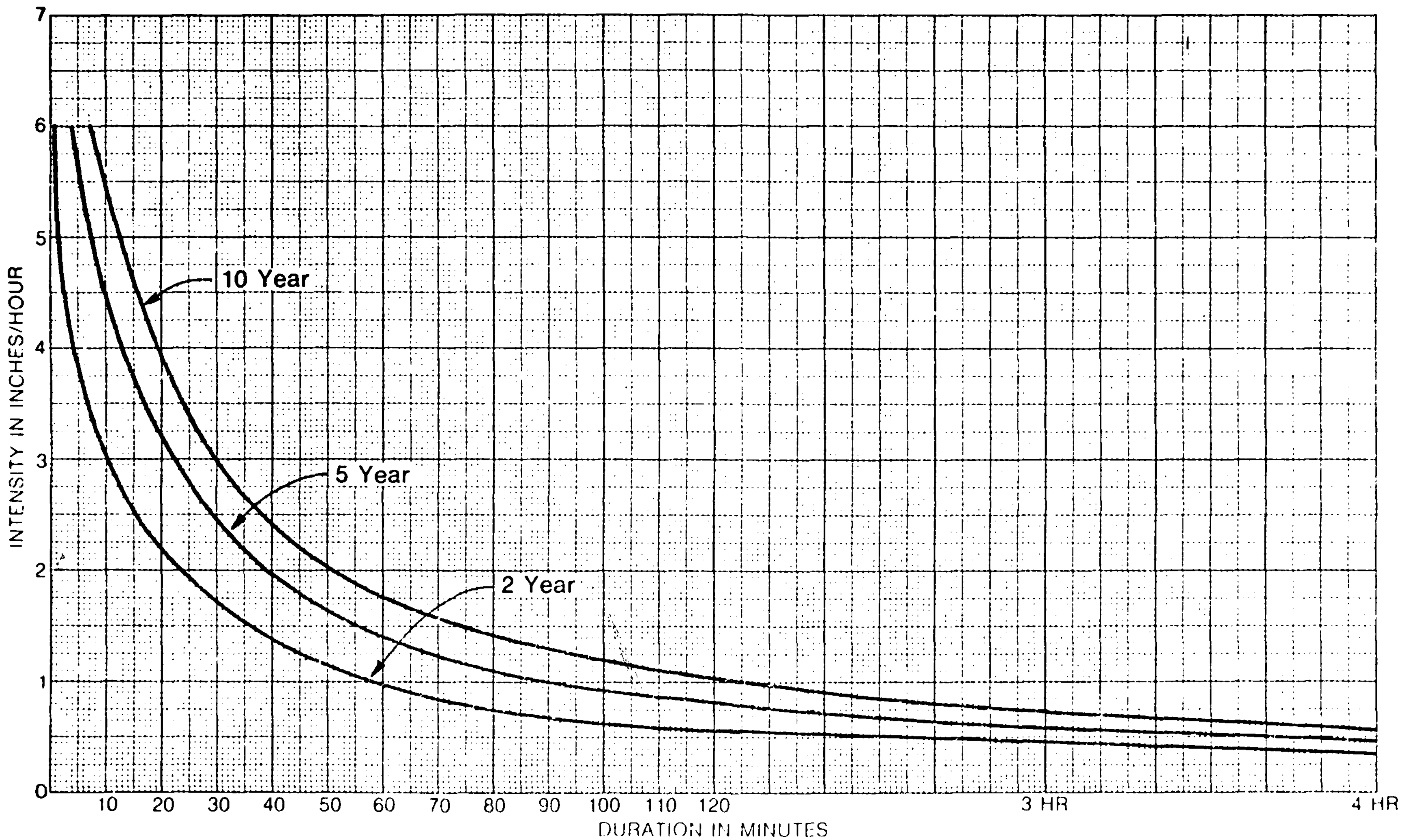


FIGURE 5 - Intensity-Duration-Frequency Chart
Devils Lake and Grand Forks

FUTURE CONDITIONS

The population of Grand Forks in 1975 was 41,986. The projected population for Grand Forks in 2000 is 62,128. The city's estimate of future urban land needs between 1975 and 2000 is 3,300 acres. The study area is, therefore, over six times as large as the estimated land development needs during the next 22 years. However, the recent rate of development has exceeded short-term projections, and it is likely that the needs for development through the year 2000 will exceed the 3,300-acre estimate. Because the city has zoning authority 2 miles beyond its corporate limits, city officials desire an urban drainage plan that includes their total sphere of influence. This desire established the outer limits of the study area. Although the undeveloped land in the study area far exceeds the development needs for the foreseeable future, for hydrologic purposes each area was treated as if it were fully developed. The composite runoff coefficient for the developed condition was calculated by assuming that the land uses within each area were in the same ratio as the land use in the overall 1975-2000 urban land needs estimate.

Estimated peak runoff for each drainage area under assumed future development conditions for 5- and 10-year frequency rainfall events is shown in tables 1 and 2, respectively.

EXISTING DRAINAGE PATTERNS

The existing rural road ditches (not including the legal drains) are generally shallow and the slopes follow the ground topography. Because of the flatness of the area and the lack of distinctive drainage areas, minor changes in the existing condition (such as road improvements, changes in hydraulic structures, and landscaping) can alter the established drainage areas. As an area undergoes development, the potential for these changes is high. If this factor is recognized during development and properly managed, it can be used to good advantage. However, if it is not recognized or ignored, it can generate significant water resource problems.

As larger rainfall events occur, natural features which form drainage area boundaries during smaller, more frequent events are over-topped and two or more drainage areas can effectively become one. It was assumed in this report that the boundaries of the existing drainage areas would remain unchanged during future development. It was also assumed that the drainage area boundaries would remain unchanged for the particular rainfall events considered in the hydrologic analysis. Table 3 presents a general description of the drainage patterns within each defined drainage area. These patterns are also visually displayed on figure 4.

Table 3 - Drainage patterns

Area	Natural drainage
A	Bounded on the north by the English Coulee diversion and on the southwest by the Burlington Northern railroad. Highway 2 cuts through the area in an east-west direction. Natural drainage is from the southwest into the diversion channel along Highway 2 and then north into the English Coulee floodway. An auxiliary channel 1 mile north of Highway 2 also receives runoff from the area and also discharges into the floodway. The northeast corner of the drainage area is cut in a north-south direction by Interstate 29. The natural drainage from this portion of the area flows into the English Coulee floodway and the Red River of the North just downstream of the mouth of English Coulee.
B	Drains naturally into the east end of the Legal Drain 18 and is carried east under Interstate 29 and into English Coulee. A sma subdrainage area in the southeast corner of the drainage area flo into an intermittent tributary of English Coulee near the intersection of Interstate 29 and the Burlington Northern Railroad trac About 600 acres in the northeast quadrant of the drainage area is within the corporate limits of Grand Forks and 600 acres in the west end of the drainage area is outside the study limits.
C_1	Bounded by Interstate 29 on the east and receives runoff from area C_2 outside the study area. Runoff from the area is generally north into Drain 9 which flows into English Coulee.
E	Drainage flows either overland directly into English Coulee or into the small intermittent tributaries of the coulee. This area has more relief than any other drainage area in the study limits.
I	Area is bounded by Interstate 29 on the west. Runoff flows overland into English Coulee and its tributaries.
J	Area is bounded by Interstate 29 on the west. Runoff from the south end of the area flows overland and through existing road ditches north into the east branch of English Coulee.
K	Area is bounded by Interstate 29 on the west and Legal Drain 4 on the south. Runoff flows northeast until it is intercepted by Belmont Coulee. Belmont Coulee discharges into the Red River of the North.
L	Area is bounded by Legal Drain 4 on the south and the Red River of the North on the east. Runoff flows overland into either Cole Creek or the Red River of the North.
R	Commercially developed area along Highway 81. Runoff flows into either English Coulee or the Red River of the North.

PLAN FORMULATION

The purpose of plan formulation is to develop a plan which provides the best use of resources to meet the urban drainage needs of the Grand Forks urban area. The intent of this report is not to develop a final plan but to identify, evaluate, and compare alternative measures with a view toward feasibility and acceptability. More advanced formulation in stage 3 will be aimed at selecting a plan of improvement for recommendation. Stage 3 studies will center around the refinement of alternative measures found feasible and acceptable in this report.

PLANNING OBJECTIVES

The objectives of planning for future urban drainage needs are to identify alternative solutions that will:

a. Use and preserve, to the extent possible, desirable existing natural systems.

b. Reduce capital and environmental costs to the community.

c. Prevent loss of life and property resulting from runoff from any foreseeable rainfall event.

d. Provide an acceptable degree of convenient access to property during and following frequent rainfall events.

URBAN DRAINAGE PRINCIPLES

Nationwide experience indicates that stormwater has rarely been well managed. Past practices sought maximum convenience at an individual site by the most rapid possible elimination of excess surface water after a rainfall and the containment and disposal of that water as quickly as

possible through a closed system. Such approaches have resulted in increased frequency of downstream flooding, often accompanied by diminishing groundwater supplies, increased soil erosion, and decreased water quality.

Stormwater runoff management is currently undergoing a significant redirection with new emphasis on the desirability of detaining or storing rain where it falls. This approach applied to individual sites or developments often has beneficial cumulative effects by attenuating both peak runoff and total short-term runoff. Basic principles of stormwater runoff management have been developed, as follows:

a. Ideally water should be retained or absorbed to the extent that urban runoff is not significantly different than before development.

b. Collection, storage, conveyance, and treatment facilities should strike a balance among costs (economic, environmental, and social).

c. The total urban drainage system should strive to improve effectiveness of natural systems rather than negate, replace, or ignore them.

d. Stormwater should be treated as a resource to replenish the total water resources of the area.

e. Property owners and the community should share responsibilities for stormwater management.

f. The total urban drainage system should consist of two components: (1) a major system to prevent or minimize damage to property and physical injury and loss of life which may occur during or after a very infrequent or unusual storm, and (2) a minor system to eliminate or minimize inconvenience or disruption of activity as a result of runoff from more frequently occurring, less significant storms.

ALTERNATIVES

Alternatives for urban drainage can be divided into three categories:

a. Storage alternatives.

b. Alternative routes of conveyance.

c. Alternative methods of conveyance.

The most effective urban drainage system is a combination of many alternative features. A complete systems analysis of possible combinations of alternatives is beyond the scope of this prelimina[illegible] [illegible]ud[illegible] For this report the alternatives are discussed [illegible] evaluate[illegible] [illegible]. On the basis of preliminary evaluations, judgments are made [illegible] [illegible]he potential of the alternatives to fit into an overall urban drainage syste[illegible] for future urban development in Grand Forks. The overall impacts of selected combinations of alternatives were assessed by evaluating impacts of selected combinations of alternatives was made by evaluating several typical drainage units and applying the units as appropriate to the entire study area to approximate a complete system.

Storage Alternatives

An important factor in urban drainage is storage. [illegible]roviding storage can reduce peak runoff rates; aid in replenishment of the water supply; provide for attenuation; and lessen the possibility of down-stream flooding, stream erosion, and sedimentation. Storage can occur naturally within a drainage area or be added to the system.

In areas where topographic relief and drainage patterns permit, where storing or flooding is not practical for economic reasons, or where extreme public inconvenience is involved, conveyance systems are designed

to remove peak runoff as it occurs. However, where natural topography provides storage areas for runoff or where the costs of conveyance systems are too high, storing runoff in selected areas is desirable. Although flooding in urban areas is undesirable, if the depth of flooding is controlled and critical areas are avoided, some limited short-term flooding is usually acceptable because of the costs associated with providing a system capable of preventing all flooding under all conditions. For urban drainage this trade-off is made by designing the system to prevent flood damages from the 5- to 25-year rainfall event.

For this report nine storage alternatives were considered as discussed in the following paragraphs.

Rooftop Storage - Horizontal rooftops can be used for temporary stormwater detention without inconveniencing pedestrians or motorists. Many flat roofs of commercial and industrial buildings pond significant amounts of water not necessarily by design. However, rooftop storage is most effective and causes the fewest problems when it is designed into the original building plans and not provided as an afterthought. Structural requirements for providing rooftop detention can be incorporated into building codes.

Plaza/Parking Lot Storage - Temporary storage of stormwater on plazas and in parking lots is an effective method for detention of stormwater. Parking areas must be designed so that ponding does not cause an intolerable inconvenience to users. Ponding areas should be located in the areas least used. In most cases, water would pond to a depth not greater than 12 inches and probably be drained within 30 minutes after a rainfall. Parking lots are often designed so that runoff is channeled to adjacent grassed areas for temporary storage. This reduces inconveniences for users of the lot but increases requirements for real estate.

Street Storage - Good planning and proper use of the hydraulic carrying capacity of the street system can substantially help reduce the size of a storm sewer system in newly urbanized areas. Proper use of the hydraulic carrying capacity of the street involves designing some streets for partial inundation. Local streets can be inundated with little effect on vehicular traffic. The small number of cars involved could move slowly through water 4 to 6 inches deep. Inundation of selected streets is an effective way of surcharging storm sewers to increase their hydraulic carrying capacity. From 20 to 25 acre-feet per square mile can be available for temporary storage of runoff in urban areas.

Dry Impoundments - A dry impoundment or detention basin is a permanent structure designed to provide temporary storage for stormwater runoff and thereby reduce the peak discharge rates. These impoundments require some topographic relief. In Grand Forks, where topographic relief is minimal, development of these facilities would have to be integrated with development of the area so that excavation, borrow, and landscaping from other urban developments could be used to create detention areas. Recreation areas, greenbelt areas, and neighborhood parks provide excellent settings for detention basins. Since the areas are used for ponding for short periods, little conflict occurs with other types of low density uses. The temporary storage of water is accomplished by providing a controlled release rate. When the stormwater inflow into the basin exceeds the controlled release rate, the runoff in excess of the release rate is stored in the basin. The controlled release rate is based on a controlling downstream condition. The system is designed so that the basin drains completely dry after runoff has ceased. Where streets cross drainageways, the roadway embankment can be used as an effective dam for only moderate additional cost.

Permanent Impoundments - A permanent impoundment is similar to a dry impoundment except that a permanent pool is maintained for aesthetics and recreation. A deeper detention area is required to maintain a minimum depth permanent pool plus capacity for storage of runoff. A permanent impoundment should be located where the surface runoff from the contributing drainage area is sufficient to maintain an adequate pool level. The "blue-green" concept, as this plan is called, is most applicable to humid parts of the country where average rainfall is 30 inches or more. Areas with less rainfall have problems maintaining adequate pool levels and avoiding stagnation, eutrophication, and excessive aquatic growth.

Channel Storage - Channels, both natural and man-made, provide significant storage capacity within an urban drainage system. Whenever the actual flow within a channel is less than its flow capacity, a potential exists for storage within the channel. Controls such as check dams, overflow weirs, and outlet structures may be necessary to pond water in the channels when the flow rate is less than channel capacity. The top section of a channel can be widened to provide storage volume when the capacity of the primary channel section is exceeded.

Swale Storage - A common drainage practice for urban developments is the use of swales. Swales are located either on the side or back of property lines and drain longitudinally through the block. Swales should be wide and shallow with a rough surface and gentle slopes. Swales can be developed either by taking advantage of natural features or by design. A network of swales can be included in a development plan for an urban area.

Subsurface Detention - Subsurface detention involves constructing subsurface structures to store runoff during storm peaks. After peak runoff passes, the excess flow stored in the structure is released back to the system. The storage capacity can be provided with underground

storage tanks or oversized storm sewers and appurtenances. These systems have generally been used in high cost developments where little or no open space for alternative systems is available. For undeveloped areas such as those considered in this study the systems appear to have little potential.

Infiltration - Infiltration is a method whereby surface runoff is temporarily stored to allow percolation into the soil, rather than allowing runoff to follow natural surface courses. Infiltration systems currently used are infiltration basins, diffusion wells, deep infiltration wells, and seepage pits and trenches. These systems can recharge groundwater supplies. The relative impermeability of the soil in the Grand Forks area would severely limit the capability of these systems. Groundwater sources in the Grand Forks area are limited. Recharge of the Dakota aquifer may be possible; however, the aquifer is saline and fresh water introduced in this formation would probably be lost as a source of usable water supply.

Storage alternatives are summarized in table 4.

Table 4 - Storage alternatives

Alternative	Impacts
1. Rooftop storage	a. Convenient. No direct effect on human activity.
	b. Limited in application to commercial and industrial buildings.
	c. Poses no safety hazard to children.
	d. Increases building construction and maintenance costs.
	e. Increases potential for damage to buildings and contents.
	f. Immediate detention. Holds the water where it falls.
	g. Costs borne directly by property owners.
2. Plaza/parking lot storage	a. No structural limit on depth of storage possible.
	b. Large parking areas typical at shopping centers, apartment complexes, office buildings, and industrial plants can provide considerable amounts of storage.
	c. Maintenance and inspection are convenient and inexpensive.
	d. Requires more detailed planning and design to avoid conflicts with primary use.
	e. Interference with vehicle and pedestrian access during periods of storage.
	f. Increased runoff that results from lot or plaza is mitigated by the party causing the effect.
	g. Very limited application in residential areas.
	h. Costs borne directly by property owner.

Table 4 - Storage alternatives (cont)

Alternative	Impacts
3. Street storage	a. Increased storage capacity at little additional cost. b. Hinder traffic movement. c. Increased street maintenance because of sediment and debris accumulation. d. Potential exists for overtopping curbs and affecting adjacent property. e. Undesirable long-term ponding in low points. f. Close coordination of street and sewer designs necessary.
4. Dry impoundments	a. Reduces peak flows to reduce costs of conveyance and treatment systems and impact on downstream conditions. b. Costly to develop unless integrated with other development projects. c. Very compatible with single-family and multifamily residential development and the Planned Unit Development concept. d. Impoundments are easily maintainable if properly designed. e. Gives maximum protection for capacity of impoundment since permanent pool is not maintained. f. Allows for multipurpose use of area. g. Provides some settling of solids before stormwater reaches major drainways. h. Accumulated sediment may become unsightly if not removed.

Table 4 - Storage alternatives (cont)

Alternative	Impacts
5. Permanent impoundments	a. Very costly to develop where topographic relief does not exist.
	b. Allows for multipurpose use of area.
	c. Accumulated sediment must be removed periodically.
	d. Provides some settling of solids before stormwater reaches major drainageways.
	e. Aesthetically pleasing if properly designed.
	f. Potential problems with stagnation, eutrophication, aquatic growths, and vector breeding in subhumid areas.
	g. Reduces peak flows to reduce costs of conveyance and treatment systems and impact on downstream conditions.
	h. No effective storage from permanent pool.
	i. Potential safety hazards for children.
6. Channel storage	a. Effective method of utilizing excess channel capacity during runoff events smaller than design.
	b. Enlarged top sections of channels provide buffer zones between the primary ditch section and adjacent land use.
	c. Most desirable when natural land features can be utilized.
	d. Increased infiltration.

Table 4 - Storage alternatives (cont)

Alternative	Impacts
7. Swale storage	a. Very effective where gradients are flat.
	b. Can be developed during urban development with little additional cost.
	c. Environmental effects very minimal.
	d. Increased infiltration.
	e. Costs borne directly by property owner.
8. Subsurface detention	a. High first costs.
	b. Maintenance costs high.
	c. Environmental effects minimal.
9. Infiltration	a. Methods generally involve high first costs and high maintenance costs.
	b. Efficiency low under most conditions.
	c. Most effective in areas with highly permeable soil.
	d. Effective method for storing water for future use.
	e. Potential for contamination of groundwater.

Alternative Routes of Conveyance

This alternative addresses possible routes for directing runoff from the drainage areas to a point of discharge from the area. It is assumed that ultimately all excess runoff will flow into the Red River of the North unless alternatives such as infiltration and groundwater recharge are implemented. Table 5 presents a matrix of alternative routes and identified impacts for each drainage area within the study limits.

Table 5 - Drainage route alternatives

Drainage area	Alternative route	Impacts
A	1. North to English Coulee diversion [1]	a. Avoids possible flooding problem along English Coulee.
		b. Takes advantage of natural drainage patterns and existing floodway.
		c. Decreases capacity of floodway to accommodate flow from upstream areas.
		d. Closest and most convenient discharge point.
	2. Southwest portion to Legal Drain 9.	a. Directs flow against natural slope of land, thus increasing depths of cut for pipes or channels.
		b. Adds to the flow of English Coulee through Grand Forks.
	3. Along Highway 2 to English Coulee	a. Adds to the flow of English Coulee through Grand Forks.
		b. Collection and conveyance of runoff difficult.
		c. Possible alternate route when English Coulee floodway capacity is exceeded.
		d. Requires development/improvement through developed commercial and industrial area.

Table 5 - Drainage route alternatives (cont)

Drainage Area	Alternative route	Impacts
B	1. To English Coulee via Legal Drain 18. (1)	a. Adds to flow of English Coulee through Grand Forks.
		b. Takes advantage of natural drainage patterns.
		c. Requires development/improvement of drainageway through highly developed commercial and residential area.
	2. To English Coulee diversion	a. Decreases capacity of floodway to accommodate flow from upstream areas.
		b. Decreases flooding potential of English Coulee.
		c. Floodway access convenient via existing ditches.
	3. To English Coulee via Legal Drain 9.	a. Directs flow against natural slope of land, thus increasing depths of cut for pipes or channels.
		b. Adds to flow of English Coulee through Grand Forks.
		c. South portion of drainage area very accessible to Legal Drain 9.
C_1	1. To Legal Drain 9(1)	a. Takes advantage of natural drainage patterns.
		b. Adds to flow of English Coulee through Grand Forks.
		c. South portion of drainage area considerable distance from Legal Drain 9.

Table 5 - Drainage route alternatives (cont)

Drainage area	Alternative route	Impacts
	2. South portion to Legal Drain 4.	a. Directs flow against natural slope of land, thus increasing depths for pipes or channel.
		b. Legal Drain 4 adjacent to this area.
		c. Reduces flow of English Coulee through Grand Forks.
	3. South portion east to Red River of the North	a. Reduced flow into English Coulee through Grand Forks.
		b. Long distance for conveyance of runoff to the Red River of the North.
		c. Requires development of drainage facilities through other areas that will probably be developed before area C_1.
E	1. To English Coulee(1)	a. Takes advantage of existing drainage patterns.
		b. Good potential for natural storage in this area.
		c. Adds to flow of English Coulee.
		d. Most obvious and least costly alternative for this area.
	2. North portion to English Coulee floodway	a. Reduced flow into English Coulee.
		b. Reduced capacity of floodway to accommodate flows from upstream areas.

Table 5 - Drainage route alternatives (cont)

Drainage area	Alternative route	Impacts
I	1. To English Coulee [1]	a. Takes advantage of natural drainage pattern of this area.
		b. English Coulee and small intermittent streams exist which, if preserved, will facilitate natural drainage from much of the area.
		c. Only logical drainage alternative for this area.
J	1. To English Coulee [1]	a. Takes advantage of natural drainage patterns.
		b. Increases flow in English Coulee through Grand Forks.
	2. South portion to Red River of the North	a. Reduces flow in English Coulee through Grand Forks.
		b. System could be combined with drainage system for area K.
		c. Long distance of conveyance.
	3. South portion to Belmont Coulee	a. Reduces flow in English Coulee through Grand Forks.
		b. Increased flood potential on Belmont Coulee.
		c. System could be combined with drainage system for areas K and L.
K	1. South portion to Legal Drain 4.	a. Reduced flood potential on Belmont Coulee.
		b. Legal Drain 4 adjacent to this area.
		c. Directs flow against natural slope of land, thus increasing depths of cut for pipes and channels.

Table 5 - Drainage route alternatives (cont)

Drainage area	Alternative route	Impacts
K (cont)	2. West portion north to English Coulee	a. Increases flow in English Coulee through Grand Forks.
		b. Long distance of conveyance.
		c. System could be combined with drainage system for area J.
	3. To Belmont Coulee (1)	a. Aggravation of existing flood problem.
		b. Long distances of conveyance for south portion of area.
	4. South portion to Cole Creek through area L	a. Reduced flood potential on Belmont Coulee.
		b. Long distance of conveyance.
		c. System could be combined with drainage system for area L.
	5. North portion to Red River of the North	a. Reduced flood potential on Belmont Coulee.
		b. Easily accessible - conveyance distance reasonable.
L	1. South portion to Legal Drain 4.	a. Directs flow against natural slope of land, thus increasing depths of cut for pipes or channel.
		b. Legal Drain 4 adjacent to this area - conveyance distance short.
		c. Storage capacity available on Cole Creek.
	2. To Cole Creek (1)	a. Takes advantage of natural drainage patterns.
		b. Cole Creek easily accessible - conveyance distance short.
		. Storage capacity available on Cole Creek.

Table 5 - Drainage route alternatives (cont)

Drainage area	Alternative route	Impacts
L (cont)	3. North portion to Red River of the North	a. Easily accessible - conveyance distance short. b. Natural drainageways available.
R	1. To English Coulee 2. To Red River of the North	Either alternative route acceptable. Natural drainage patterns from this area should be used to the maximum extent possible.

(1) Indicates most prevalent natural drainage pattern.

Alternative Methods of Conveyance

The basic methods of conveying urban runoff are exposed systems of drainage ditches and inclosed systems of subsurface conduits. With both systems, trade-offs exist between the size of the ditch or conduit and its slope. A ditch or conduit with a steep slope has a larger carrying capacity than the same size section with a flatter slope. However, steeper slopes result in deeper cuts and more excavation within a given length. When an unreasonable depth is reached, it is necessary to either reach the point of discharge or lift the flow to a higher elevation. To lift the flow requires a pumping station and to optimize the size of the pumping station usually requires a ponding area to store the peak flows. The cost of the pumping station and ponding area must be offset by the cost savings from the reduced excavation and, in the case of conduits, reduced pipe sizes. The ideal situation is a ditch or conduit at a slope approximating the slope of the ground.

A similar trade-off exists between the flow capacity of a section and upstream storage. By providing storage before runoff enters a ditch or conduit section, the peak flow into the section can be reduced and the required size and/or slope is reduced. Storage can occur either within areas intended for storage or by encroachment upon other areas.

Ditches - Ditches are generally not practical for extensive use in urban areas because of traffic crossings, real estate requirements, and aesthetics. However, they may be acceptable for conveying flows to a primary point of discharge after collection. Collectors would consist of a system of conduits usually buried beneath the streets. The collectors would discharge into the ditches similar to the existing systems in Grand Forks that discharge into English Coulee and the Red River of the North. To be compatible with the collector system the ditches would

generally have to be a minimum of 8 feet deep to receive gravity flow from the collectors. Shallow, wide ditches often considered desirable for urban areas would not be feasible as interceptor ditches. To achieve gravity flow into the existing legal drains or the coulee would require maintaining a very flat slope along the length of the ditch. These criteria require that the slope of the ditch approximate the slope of the land which is generally 2.0 to 2.5 feet per mile. A ditch that flows against the slope of the land for 1 mile will be about 5 feet deeper at the downstream end. Therefore, for economics, it is desirable to take advantage of the slope of the land and maintain a fairly constant depth to be able to achieve gravity flow into and out of the ditch. The primary variable for sizing the ditch then becomes its width. Although the depth of the primary section of the ditch is partially determined by the aforementioned restrictions, the top section of the ditch can be widened and flattened to provide storage for runoff from a rainfall event larger than the selected design storm for the rest of the system. This wide, flat top section can serve as a buffer zone between the deeper section and the adjacent land use. It also is consistent with the basic urban drainage principle of providing for both a major and minor drainage system.

Conduits - The same criteria for depths and slopes apply for interceptor sewers if gravity conditions are to be maintained. For conduits, however, as slopes become flatter, the loss of hydraulic efficiency becomes even more evident than for ditches as costs rise more dramatically. For good hydraulic efficiency, storm sewer conduits should be constructed at a slope of about 10 feet per mile. With a minimum cover of 3 feet, a 60-inch conduit, for example, would initially require a depth of cut of 8 feet. Assuming the land slopes 3 feet per mile, and a pipe slope of 10 feet per mile, the depth of cut at the end of a 1-mile run would be 15 feet. In the study area, the extremities of the drainage areas are typically 1 mile or more from a primary point of discharge (coulee, legal drain, or floodway). Basically two options exist for conduit interceptors:

a. Construct the conduit at a desirable slope to minimize conduit sizes and use pumping stations to lift the flow when depth of cut becomes unreasonable.

b. Construct the conduit at a slope where gravity conditions can be maintained throughout the system and use larger conduit sizes to compensate for the flat slopes.

A disadvantage of a conduit is that if the slope is controlled, not only does the cost increase because of larger conduit sizes, but the depth of the conduit section also increases. This compounds the prol of maintaining the flow line above the receiving ditch. In contrast. the capacity of an interceptor ditch can be increased by widening th section and not changing its depth.

COMBINED ALTERNATIVES

The optimum urban drainage system is a combination of the alternatives previously discussed. It is beyond the scope of this stage of study to undertake a detailed systems analysis involving modeling and extensive rainfall routing through the drainage basin. However, a method was desired to combine basic alternatives, apply the combined alternatives to the study area, and assess them.

All the land in the study area is within 3 miles of an existing major drainageway (Red River of the North, English Coulee, English Coulee floodway, or a legal drain). Runoff from the study area was assumed to ultimately be discharged into one of the drainageways. From a basic unit of one section (640 acres), three types of catchment units were observed.

A Units - Sections adjacent to the existing major drainageways. Approximately 70 percent of the units are in this category.

B Units - Sections upstream and adjacent to the A units. These units are within 1 mile of the existing major drainageways and account for about 20 percent of the study area.

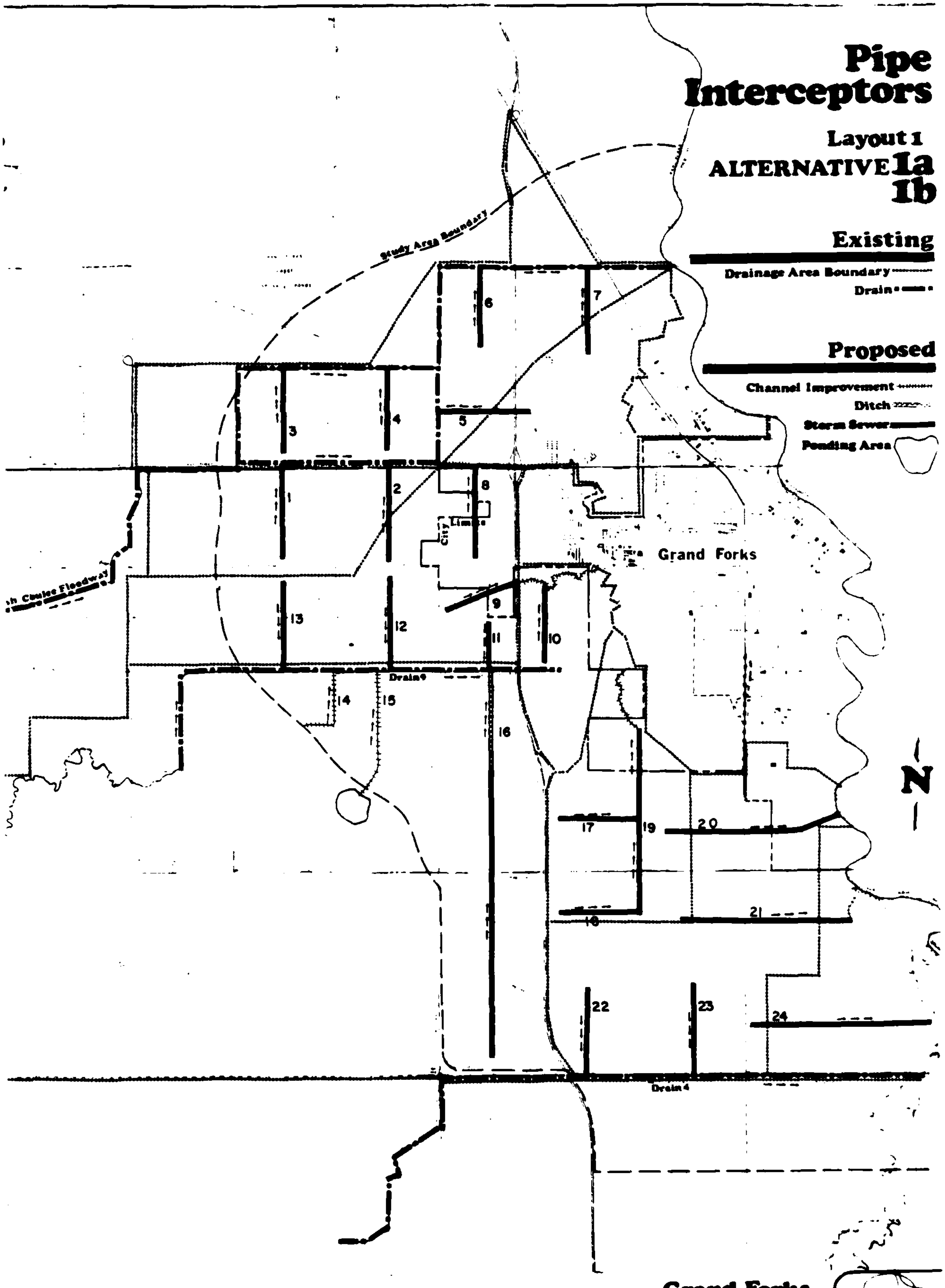
C Units - Sections upstream and adjacent to the B units. These units are within 2 miles of the existing major drainageways and account for only about 10 percent of the study area.

By taking a set of combined alternatives, evaluating it for the three basic units (A, B, and C), and applying the typical catchment units to the entire study area, it is possible to approximate a total combined system of alternatives. Although this analysis would not be appropriate for detailed studies, it was used in this preliminary analysis primarily to indicate magnitude of impacts and determine the scope and direction of future study.

The possible combinations of basic alternatives would be too numerous to analyze. Therefore, basic alternatives were combined to generate a range of combined alternatives. The combined alternatives consist of combinations of (1) methods of conveyance, (2) routes of conveyance, and (3) storage alternatives. A fourth variable, the design storm frequency, was introduced to demonstrate its impact. Several combined alternatives were analyzed with both a 5- and a 10-year design rainfall for runoff.

Routes of conveyance were analyzed and two basic layouts were developed for the analysis of combined alternatives. Layout 1 was used for alternatives 1a, 1b, and 2a (see figures 6 and 7). Layout 2 was used for alternatives 1c, 1d, 2b, 3a, and 3b (see figures 8, 9, and 10).

The assumed layout of the collection system for runoff within each catchment unit is shown on figure 11. The hydrologic routing of runoff and the sizing of drainage facilities were calculated from this assumed layout. Collection and conveyance within the 1-square mile unit were not examined in detail. The collection system was assumed to deliver runoff to the major interceptor passing through the unit. Only the impacts of the interceptor system were considered in the combined alternatives and the cost analysis.


Pipe Interceptors
Layout 1
ALTERNATIVE 1a 1b
Existing
Drainage Area Boundary
Drain
Proposed
Channel Improvement
Ditch
Storm Sewer
Ponding Area
Study Area Boundary
Grand Forks
City Limits
Drain 9
Drain 4
N
1
2
3
4
5
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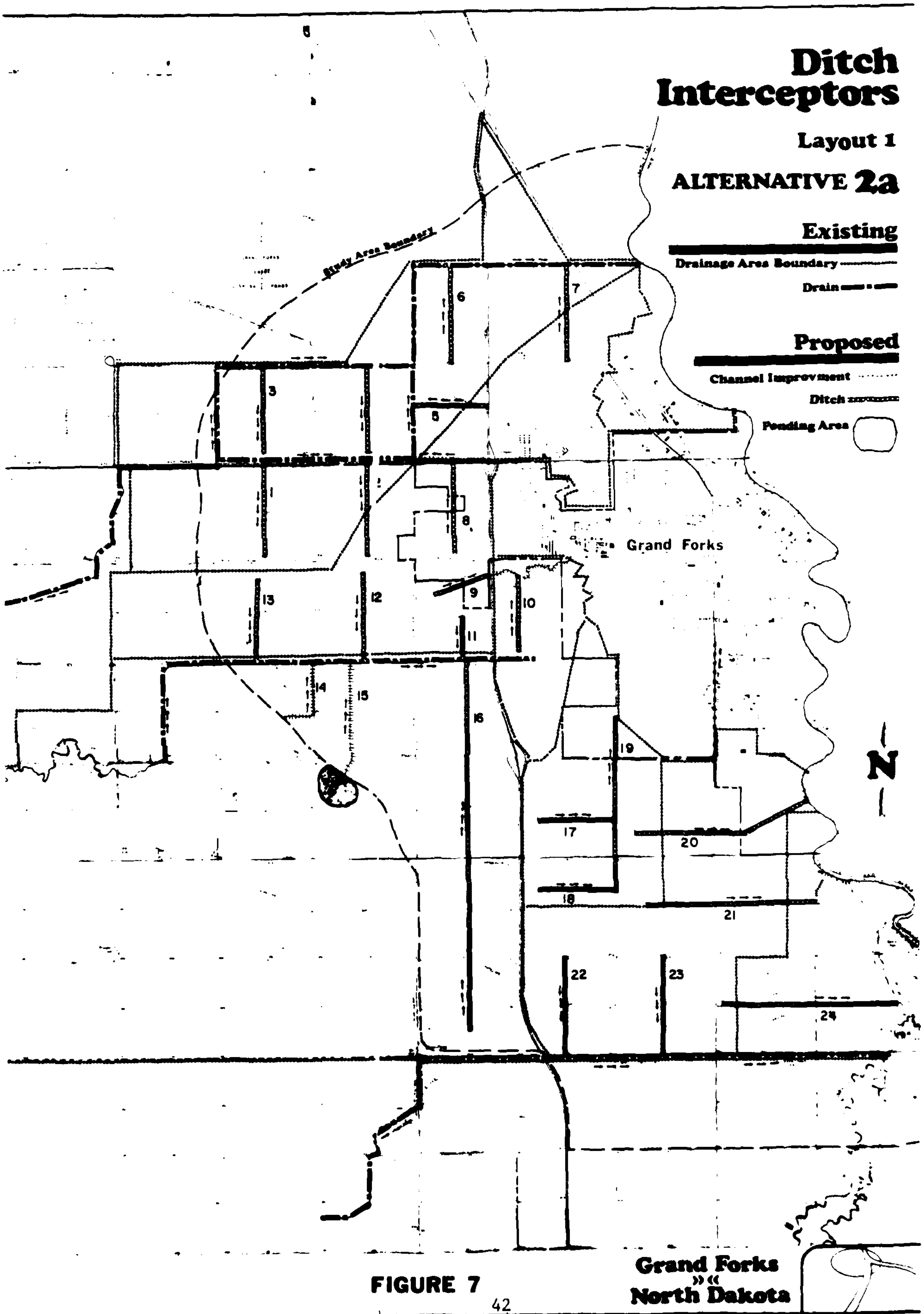
Grand Forks
North Dakota

FIGURE 6



Ditch Interceptors
Layout 1
ALTERNATIVE 2a
Existing
Drainage Area Boundary
Drain
Proposed
Channel Improvment
Ditch
Ponding Area
Study Area Boundary
Grand Forks
1
2
3
5
6
7
8
9
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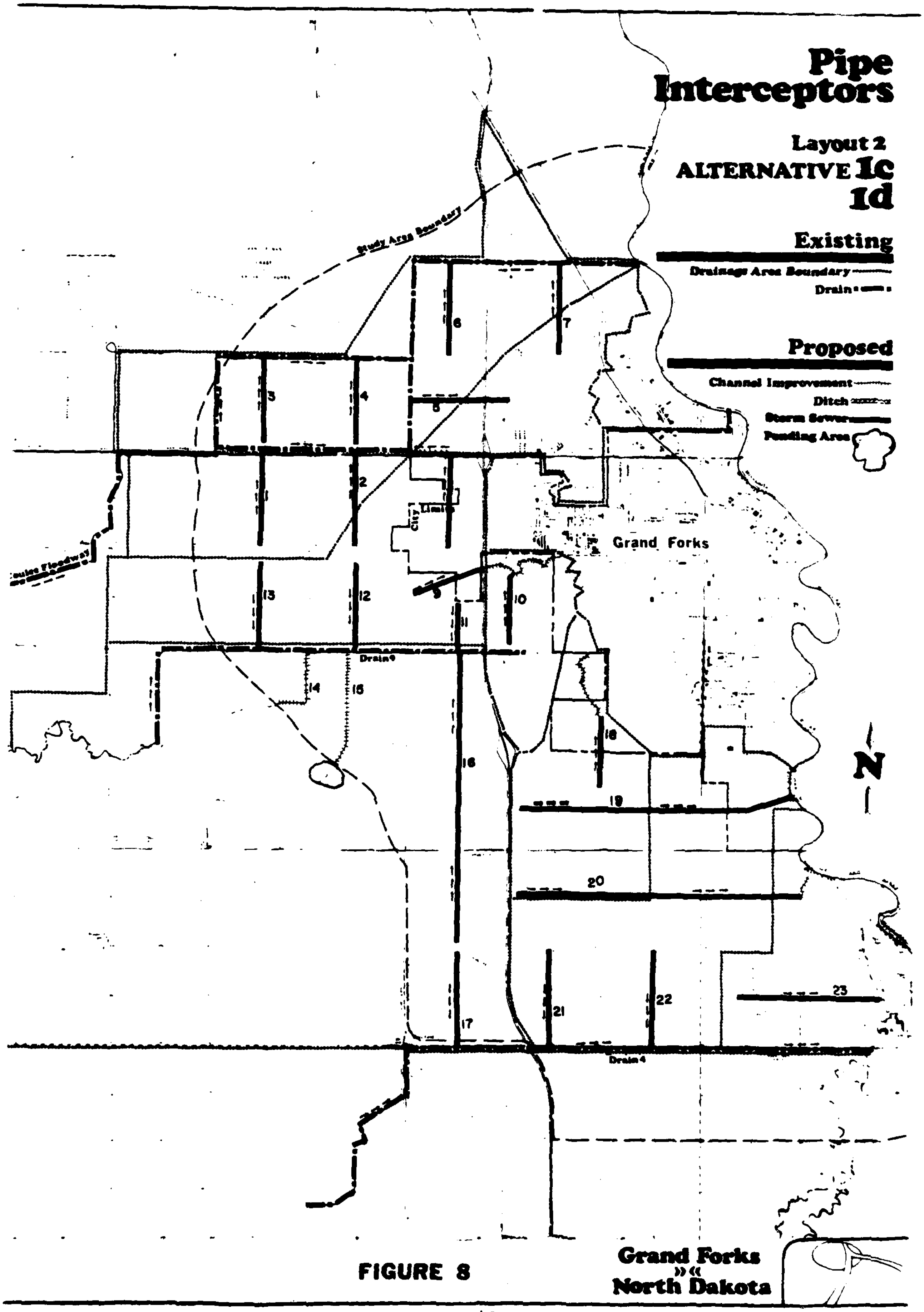
N
Grand Forks
North Dakota

FIGURE 7



Pipe Interceptors
Layout 2
ALTERNATIVE 1c
1d
Existing
Drainage Area Boundary
Drain
Proposed
Channel Improvement
Ditch
Storm Sewer
Ponding Area
Study Area Boundary
Floodway
City Limits
Grand Forks
Drain 9
Drain 4
N
3
4
5
6
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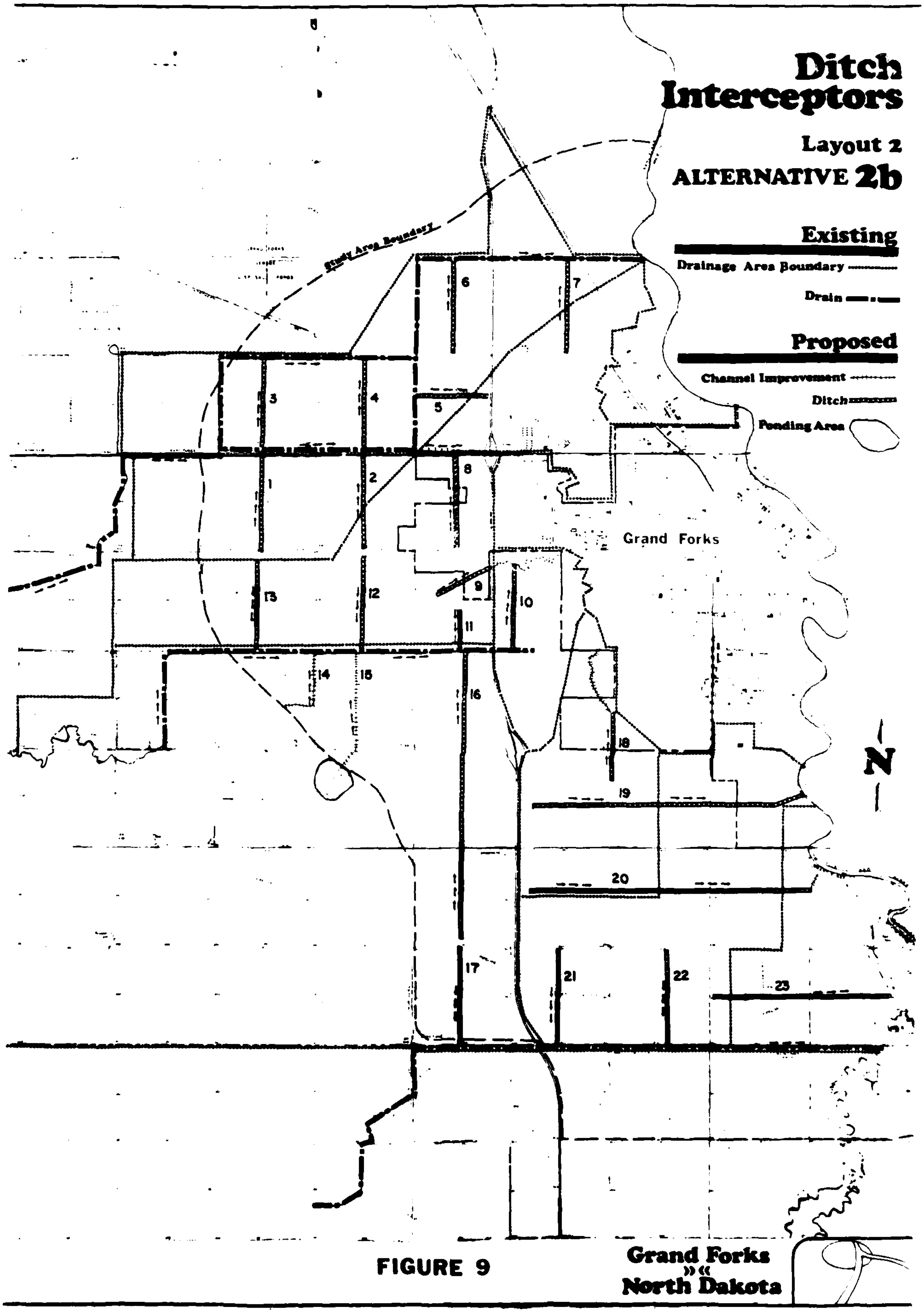
Grand Forks
North Dakota

FIGURE 8


Ditch Interceptors
Layout 2
ALTERNATIVE 2b
Existing
Drainage Area Boundary
Drain
Proposed
Channel Improvement
Ditch
Ponding Area
Study Area Boundary
Grand Forks
1
2
3
4
5
6
7
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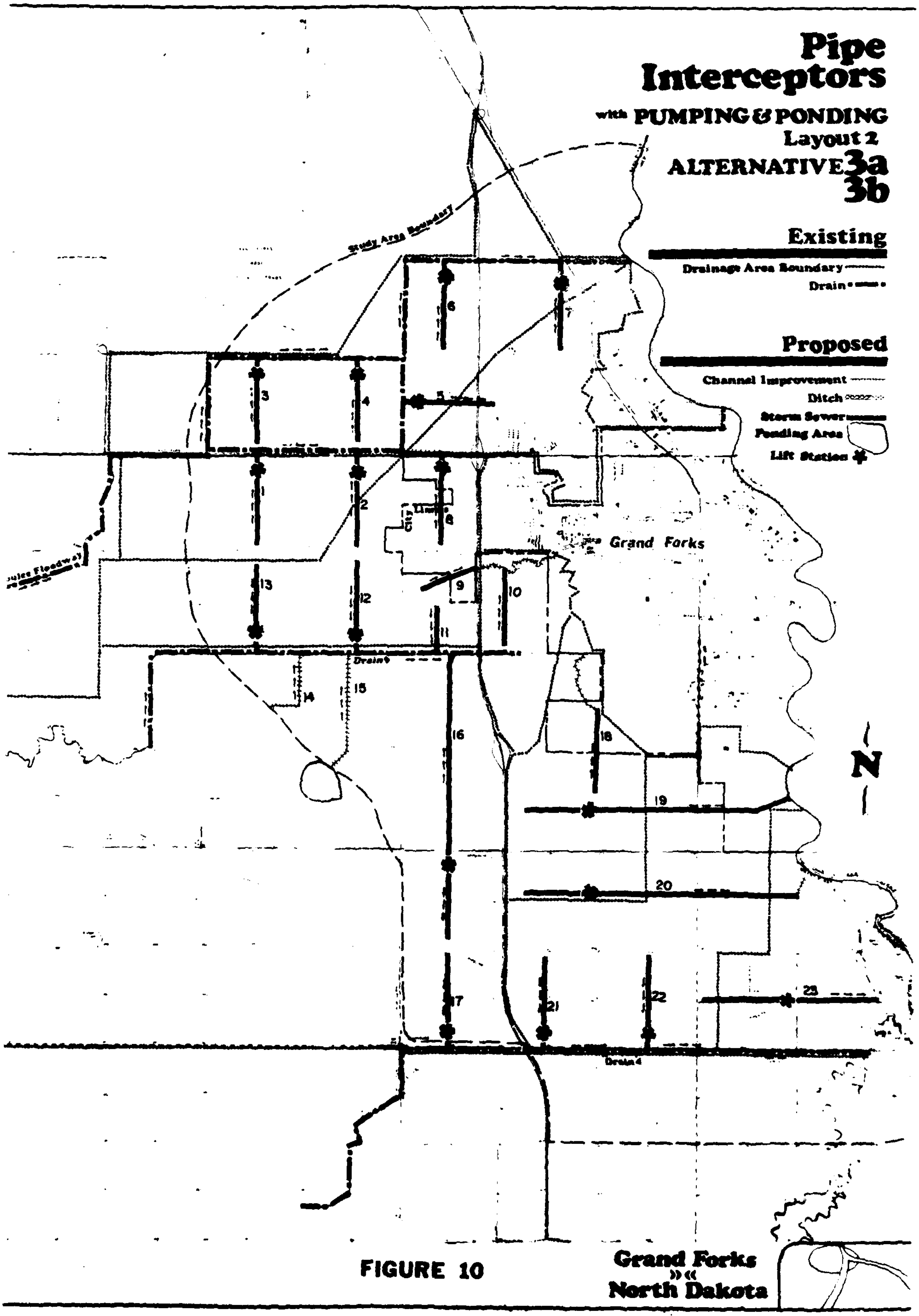
N
Grand Forks
North Dakota

FIGURE 9



Pipe Interceptors
with PUMPING & PONDING
Layout 2
ALTERNATIVE 3a 3b
Existing
Drainage Area Boundary
Drain
Proposed
Channel Improvement
Ditch
Storm Sewer
Ponding Area
Lift Station
Study Area Boundary
Grand Forks
City Limits
Drain 9
Drain 4
N
1
2
3
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Grand Forks
North Dakota

FIGURE 10

CATCHMENT UNIT

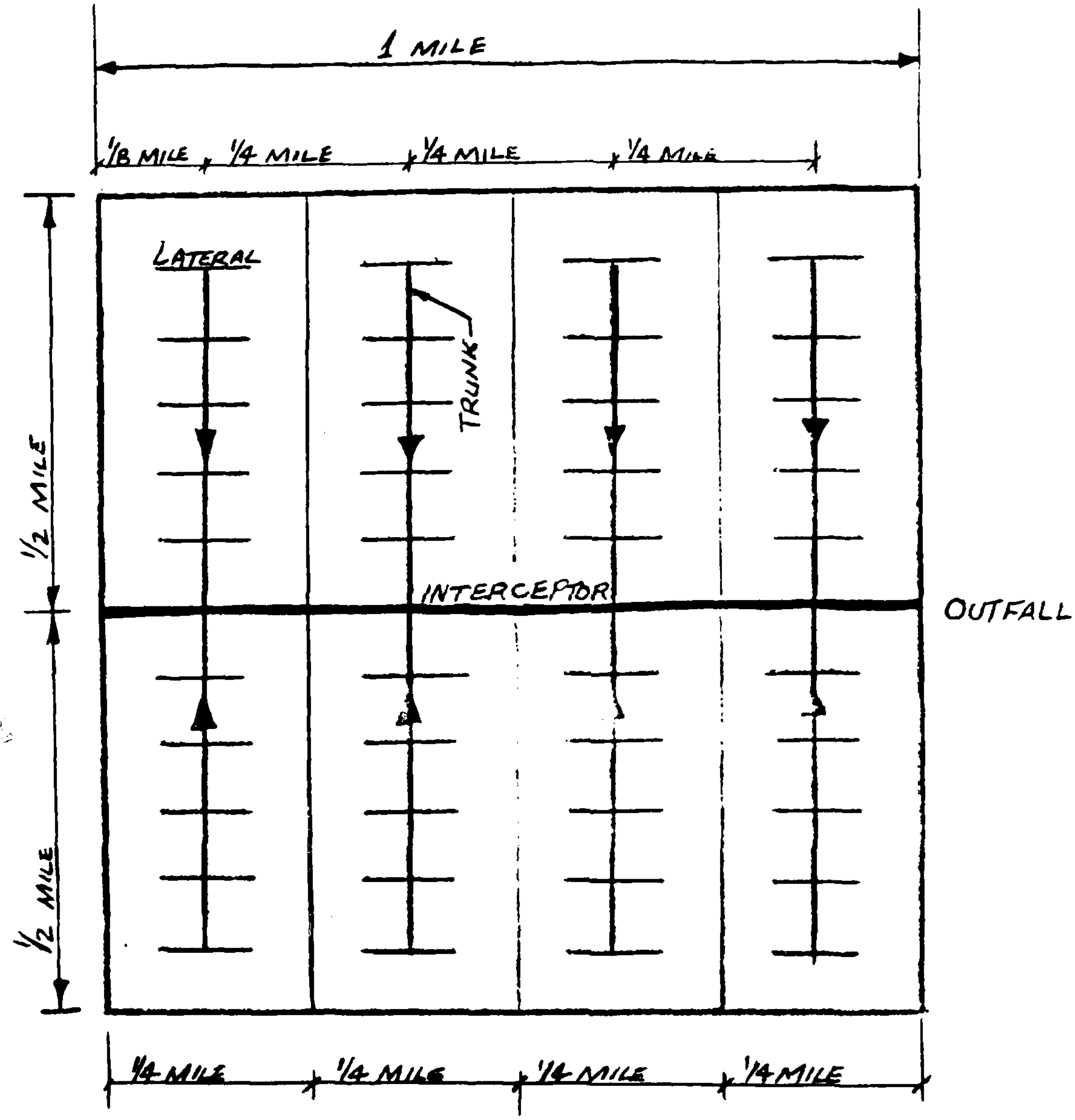

FIGURE 11

Alternative 1

This alternative considers development of an inclosed system of interceptor conduits to convey runoff flows from the catchment units to the existing major drainageways. Runoff was determined by the rational formula using a composite runoff coefficient of 0.35. To avoid pumping requirements it was considered desirable to maintain gravity flow between the collector system, the interceptors, and the existing drainageways. This criterion required a minimum depth of 8 feet for the interceptors. The outlet elevations of the interceptors were controlled by the depths of the existing drainageways at the point of discharge. This resulted in a slope on the interceptors of 0.0005 foot per foot which approximates the natural slope of the ground. This limitation on slope increases the required conduit sizes but avoids requirements for pumping stations. Tables 6, 7, 8, and 9 and figures 6 and 8 summarize the facilities required within the study area for development of this alternative. In addition to the interceptor conduit, the analysis includes costs for the following appurtenances:

a. Manholes - five per mile of interceptor.

b. Outlet structures and flap gates at all outlets.

c. All excavation and installation costs for the interceptors.

Variations of this alternative were analyzed by changing the interceptor layout and the design storm frequency as follows:

Alternative	Route	Design storm
1a	Layout 1	5-year
1b	Layout 1	10-year
1c	Layout 2	5-year
1d	Layout 2	10-year

Table 6 - Alternative 1a - interceptor conduit layout 1, 5-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches (2 on 1 sideslopes) Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvement (LF)	First cost ($1,000)
A	1			1320			1320	1320	1320													1268
	2			1320			1320	1320	1320													1268
	3			1320			1320	1320	1320													1268
	4			1320			1320	1320	1320													1268
	5			1320			1320	1320	1320													1268
	6			1320			1320	1320	1320													1268
	7			1320			1320	1320	1320													1268
B	8			1320			1320	1320	1320												2200	1312
	9			1320			1320	1320													2500	937
	11			1320			1320															507
	12			1320			1320	1320	1320													1268
	13			1320			1320	1320	1320													1268
C_1	14																				4300	147
	15																			1 - 250	6000	1182
	16			1320			1320	1320	1980	1320	1320	1320	3300	2640		12	8	5280				6784
I	10			1320			1320	1320														887
J	17			1320			1320	1320	1320													1268
	18			1320			1320	1320	1320													1268
	19								660	1320	1320	1320	3300	2640							4000	4906
K	20			1320			1320	1320	1980	1320	1320	1320	660									3452
	21			1320			1320	1320	1980	1980											1500	2202
	22			1320			1320	1320	1320													1268
	23			1320			1320	1320	1320													1268
L	24			1320			1320	1320	1980	1320	1320	420										2578
																						41,888

* Number of pumping station and flow in gallons per minute. ** Number of [illegible]

Table 7 - Alternative 1b - interceptor conduit layout 1, 10-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvement (LF)	First cost ($1000)
A	1				1320			1320	1320	1320												1472
	2				1320			1320	1320	1320												1472
	3				1320			1320	1320	1320												1472
	4				1320			1320	1320	1320												1472
	5				1320			1320	1320	1320												1472
	6				1320			1320	1320	1320												1472
	7				1320			1320	1320	1320												1472
B	8				1320			1320	1320	1320											2200	1516
	9				1320			1320	1320												2500	1080
	11				1320			1320														589
	12				1320			1320	1320	1320												1472
	13				1320			1320	1320	1320												1472
C1	14																				4300	147
	15																			1 - 250	6000	1182
	16				1320			1320	1320	1980	1320	1320	1320	3300	2640	12	8	5280				7519
I	10				1320			1320	1320													1030
J	17				1320			1320	1320	1320												1472
	18				1320			1320	1320	1320												1472
	19									660	1320	1320	1320	3300	2640						4000	5527
K	20				1320			1320	1320	1980	1320	1320	1320	660								3945
	21				1320			1320	1320	1980	1320	660									1500	2521
	22				1320			1320	1320	1320												1472
	23				1320			1320	1320	1320												1472
L	24				1320			1320	1320	1980	1320	1320	420									2955
																						47,327

* Number of pumping stations and size in gallons per minute. ** Number of ponding areas and size in acre-feet.

Table 8 - Alternative 1c - interceptor conduit layout 2, 5-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvement (LF)	First cost ($1000)
A	1			1320			1320	1320	1320													1268
	2			1320			1320	1320	1320													1268
	3			1320			1320	1320	1320													1268
	4			1320			1320	1320	1320													1268
	5			1320			1320	1320	1320													1268
	6			1320			1320	1320	1320													1268
	7			1320			1320	1320	1320													1268
B	8			1320			1320	1320	1320												2200	1312
	9			1320			1320	1320													2500	937
	11			1320			1320															507
	12			1320			1320	1320	1320													1268
	13			1320			1320	1320	1320													1268
C_1	14																				4300	147
	15																			1-250	6000	1182
	16			1320			1320	1320	1980	1320	1320	1320	3300	2640								6094
	17			1320			1320	1320	1320													1268
I	10			1320			1320	1320														887
J	18			1320			1320	1320													4000	967
	19			1320			1320	1320	1980	1320	1320	1320	5940									5865
	20			1320			1320	1320	1980	1320	1320	1320	5940								1500	5925
K	21			1320			1320	1320	1320													1268
	22			1320			1320	1320	1320													1268
L	23			1320			1320	1320	1980	1320	1320	420										2578
																						41,617

* Number of pumping stations and size in gallons per minute. ** Number of [illegible]

Table 9 - Alternative 1d - interceptor conduit layout 2, 10-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvements (LF)	First cost ($1000)
A	1				1320			1320	1320	1320												1472
	2				1320			1320	1320	1320												1472
	3				1320			1320	1320	1320												1472
	4				1320			1320	1320	1320												1472
	5				1320			1320	1320	1320												1472
	6				1320			1320	1320	1320												1472
	7				1320			1320	1320	1320												1472
B	8				1320			1320	1320	1320											2200	1516
	9				1320			1320	1320												2500	1080
	11				1320			1320														589
	12				1320			1320	1320	1320												1472
	13				1320			1320	1320	1320												1472
C	14																				4300	247
1	15																			1 25	6000	1182
	16				1320			1320	1320	1980	1320	1320	1320	3300	2640							6919
	17				1320			1320	1320	1320												1472
I	10				1320			1320	1320													1030
J	18				1320			1320	1320												4000	1118
	19				1320			1320	1320	1980	1320	1320	1320	5940								6668
	20				1320			1320	1320	1980	1320	1320	1320	5940							1500	6728
K	21				1320			1320	1320	1320												1472
	22				1320			1320	1320	1320												1472
L	23				1320			1320	1320	1980	1320	1320	420									2955
																						44,652

* Number of pumping stations and size in gallons per minute. ** Number of ponding areas and size in acre-feet.

Alternative 2

This alternative considers development of an exposed system of interceptor ditches to convey runoff flows from the catchment units to the existing major drainageways. Runoff was determined by the rational formula using a composite runoff coefficient of 0.35. As with alternative 1, it was considered desirable to avoid pumping requirements and maintain gravity flow throughout the system. This criterion required a minimum ditch depth of 8 feet and a ditch slope of 0.0005 foot per foot. With the slope and depth predetermined and assuming 2 on 1 side slopes, it was determined that an interceptor ditch with a 2-foot bottom width would carry runoff from the 5-year storm. Similarly, a ditch with an 8-foot bottom width would carry runoff from the 10-year storm. A ditch with a 2-foot bottom width was considered impractical because of difficulties with construction and maintenance. Therefore, only the 10-year storm was considered in the analysis of alternative 2. The costs for designing for runoff from the 5- or 10-year storm for this alternative would be essentially identical. Tables 10 and 11 and figures 7 and 9 summarize the requirements for development of this alternative within the study area. In addition to the costs for the ditches, the analysis includes costs for the following appurtenances:

a. Road crossings - four crossings per mile of ditch.

b. Real estate - 60-foot right-of-way.

c. Inlet structures - eight structures per mile of ditch.

d. Outlet structures and flap gates at all outlets.

This alternative was analyzed for the two basic layouts:

Alternative 2a - Layout 1, 10-year storm.
Alternative 2b - Layout 2, 10-year storm.

Table 10 - Alternative 2a - interceptor ditches layout 1, 10-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvements (LF)	First cost ($1,000)
A	1															8	8	5280				523
	2															8	8	5280				523
	3															8	8	5280				523
	4															8	8	5280				523
	5															8	8	5280				523
	6															8	8	5280				523
	7															8	8	5280				523
B	8															8	8	5280				523
	9															8	8	3960			2500	442
	11															8	8	2640				262
	12															8	8	5280				523
	13															8	8	5280				523
C_1	14																				4300	147
	15																			1 - 250	6000	1182
	16															8 8	8 12	10560 10560				1046 1200
I	10															8	8	3960				392
J	17															8	8	5280				523
	18															8	8	5280				523
	19															8 8	8 12	5280 5280			4000	523 680
K	20															8	8	10560				1046
	21															8	8	9000			1500	951
	22															8	8	5280				523
	23															8	8	5280				523
L	24															8	8	9000				891
																						16,084

* Number of pump stations [illegible] per minute. ** Number of ponding areas and [illegible] acre-feet.

Table 11 - Alternative 2b - interceptor ditches layout 2, 10-year storm

Area	Interceptor number	Conduit length (LF) — Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Ditches Bottom width	Ditches Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvement (LF)	First cost ($1000)
A	1															8	8	5280				523
	2															8	8	5280				523
	3															8	8	5280				523
	4															8	8	5280				523
	5															8	8	5280				523
	6															8	8	5280				523
	7															8	8	5280				523
B	8															8	8	5280				523
	9															8	8	3960			2500	442
	11															8	8	2640				262
	12															8	8	5280				523
	13															8	8	5280				523
C_1	14																				4300	147
	15																			1 - 250	6000	1182
	16															8 8	12 8	5280 10560				600 1046
	17															8	8	5280				523
I	10															8	8	3960				392
J	18															8	8	3960			4000	472
	19															8 8	12 8	3000 10000				568 990
	20															8 8	12 8	5000 10000			1500	628 990
K	21															8	8	5280				523
	22															8	8	5280				523
L	23															8	8	9000				891
																						15,409

* Number of pumping stations and size in gallons per minute.

** [illegible]

Alternative 3

This alternative considers development of an inclosed system of interceptor conduits to convey runoff flows from the catchment units to the existing major drainageways. Runoff was determined by the rational formula using a composite runoff coefficient of 0.35. This alternative evaluated the combination of storage and pumping with the basic interceptor conduit system. Again, the minimum 8-foot depth of conduit was maintained for gravity flow between the collection system and the interceptors. To reduce the conduit size from those determined for alternative 1, a slope of 0.002 foot per foot was assumed for the interceptor. At the end of a 1-mile run, the depth of the conduit would increase from 8 feet to about 16 feet, the maximum depth practical for construction. At this point the interceptor would discharge into a ponding area and then a lift station would pump the water into the next interceptor or into the receiving drainageway. This alternative involves a trade-off of reduced interceptor conduit sizes and the addition of pump stations and ponding areas. Tables 12 and 13 and figure 10 summarize the requirements for development of this alternative within the study area. The analysis includes first costs for the following:

a. Interceptors, including excavation and installation costs.

b. Manholes - five manholes per mile of interceptor.

c. Outlet structures and flap gates at all outlets.

d. Ponding areas - all construction and real estate costs.

e. Pumping station - all first costs. Equivalent first costs for annual operation and maintenance are estimated in column 5 of table 14.

This alternative was analyzed for layout 2 only with both a 5-year and 10-year design rainfall:

Alternative 3a - Layout 2, 5-year storm.

Alternative 3b - Layout 2, 10-year storm.

Table 12 - Alternative 3a - interceptor conduit, ponding, pumping - layout 2 - 5-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (in) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvement (LF)	First cost ($1000)
A	1	1320		1320	1320	1320													1-12000	1-47		$1,113
	2	1320		1320	1320	1320													1-12000	1-47		1,113
	3	1320		1320	1320	1320													1-12000	1-47		1,113
	4	1320		1320	1320	1320													1-12000	1-47		1,113
	5	1320		1320	1320	1320													1-12000	1-47		1,113
	6	1320		1320	1320	1320													1-12000	1-47		1,113
	7	1320		1320	1320	1320													1-12000	1-47		1,113
B	8	1320		1320	1320	1320													1-12000	1-47	2200	1,157
	9			1320			1320	1320													2500	937
	11			1320			1320															507
	12	1320		1320	1320	1320													1-12000	1-47		1,113
	13	1320		1320	1320	1320													1-12000	1-47		1,113
C_1	14																				4300	147
	15																			1-250	6000	1,182
	16	1320		1320	1320	1320	660	1320	1320	1320	2640	3300							1-12000	1-47		5,965
	17	1320		1320	1320	1320													1-12000	1-47		1,113
I	10			1320			1320	1320														887
J	18			1320			1320	1320													4000	967
	19	1320		1320	1320	1320	660	1320	1320	1320	3300	2640							1-12000	1-47		4,926
	20	1320		1320	1320	1320	660	1320	1320	1320	3300	2640							1-12000	1-47	1500	4,986
K	21	1320		1320	1320	1320													1-12000	1-47		1,113
	22	1320		1320	1320	1320													1-12000	1-47		1,113
L	23	1320		1320	1320	1320	660	1320	1320	420									1-12000	1-47		2,205
																						37,222

* Number of pumping stations and size in gallons per minute. ** Number of ponding areas and size in acre-feet.

Table 13 - Alternative 3b - interceptor conduit, ponding, pumping - layout 2 - 10-year storm

Area	Interceptor number	Conduit length (LF) Equivalent size (IN) 66	72	78	84	90	96	102	108	114	120	126	132	138	144	Ditches Depth	Bottom width	Length	Pump station EA-GPM*	Ponding areas EA-AF**	Channel improvements (LF)	First costs ($1000)
A	1		1320		1320	1320	1320												1-15000	1-55		1196
	2		1320		1320	1320	1320												1-15000	1-55		1196
	3		1320		1320	1320	1320												1-15000	1-55		1196
	4		1320		1320	1320	1320												1-15000	1-55		1196
	5		1320		1320	1320	1320												1-15000	1-55		1196
	6		1320		1320	1320	1320												1-15000	1-55		1196
	7		1320		1320	1320	1320												1-15000	1-55		1196
B	8		1320		1320	1320	1320												1-15000	1-55	2200	1230
	9				1320			1320	1320												2500	1080
	11				1320			1320														589
	12		1320		1320	1320	1320												1-15000	1-55		1196
	13		1320		1320	1320	1320												1-15000	1-55		1196
C_1	14																				4300	147
	15																			1-250	6000	1182
	16		1320		1320	1320	1320	660	1320	1320	1320	2640	3300						1-15000	1-55		5554
	17		1320		1320	1320	1320												1-15000	1-55		1196
I	10				1320			1320	1320													1030
J	18				1320			1320	1320												4000	1118
	19		1320		1320	1320	1320	660	1320	1320	1320	3300	2640						1-15000	1-55		5009
	20		1320		1320	1320	1320	660	1320	1320	1320	3300	2640						1-15000	1-55	1500	5069
K	21		1320		1320	1320	1320												1-15000	1-55		1196
	22		1320		1320	1320	1320												1-15000	1-55		1196
L	23		1320		1320	1320	1320	660	1320	1320	420								1-15000	1-55		2433
																						38,793

* Number of pumping stations and size in gallons per minute. ** Number of ponding areas and size in acre-feet.

Table 14- Summary of combined alternatives

Method of conveyance (1)	Route of conveyance (2)	Design storm frequency (3)	First cost (4)	Equivalent first costs of pump station annual O&M (5)*	Total first costs (6)
1a - Interceptor conduit	Layout 1	5 year	$41,900,000	--	$41,900,000
1b - Interceptor conduit	Layout 1	10 year	47,300,000	--	47,300,000
1c - Interceptor conduit	Layout 2	5 year	41,600,000	--	41,600,000
1d - Interceptor conduit	Layout 2	10 year	44,700,000	--	44,700,000
2a - Interceptor ditches	Layout 1	10 year	16,100,000	--	16,100,000
2b - Interceptor ditches	Layout 2	10 year	15,400,000	--	15,400,000
3a - Interceptor conduit, ponding, pumping	Layout 2	5 year	37,200,000	$1,800,000	39,000,000
3b - Interceptor conduit, ponding, pumping	Layout 2	10 year	38,800,000	2,300,000	41,100,000

* Assumes 7% interest

Summary of Impacts

Table 15 summarizes the economic, technical, environmental, and social impacts of the combined alternatives.

Table 15 - Summary of impacts of combined alternatives

Impacts	Alternative 1 Inclosed system of interceptor conduits (gravity flow)	Alternative 2 Exposed system of interceptor ditches	Alternative 3 Inclosed system of interceptor conduits in combination with storage and pumping
Economic			
First costs	1A - \$41.9 million 1B - 47.3 million 1C - 41.6 million 1D - 44.7 million	2A - \$16.1 million 2B - 15.4 million	3A - \$37.2 million (1) 3B - 38.8 million (1)
Operation and Maintenance costs	Costs slightly higher than for existing separated stormwater system in Grand Forks because of larger conduit sizes and reduced flow velocities.	Maintenance costs higher than alternative 1 due to mowing, periodic removal of accumulated sediments, and maintenance activities related to ice accumulations during spring thaw.	Costs high due to required maintenance of ponding areas and pump stations. Operation costs high due to pumping requirements. 100 percent of all runoff must be pumped.
Replacement costs	None. Expected life of facilities 50 years or more.	None. Expected life of all facilities 50 years or more.	Replacement of pumps necessary every 15 years.
Land requirements	Very minimal.	Approximately 10 acres per square mile required for ditch rights-of-way.	Approximately 50 acres required for ponding areas.

(1) Does not include operation, maintenance, and replacement costs for pumping stations.

Table 15 - Summary of impacts of combined alternatives (Cont)

Impacts	Alternative 1 Inclosed system of interceptor conduits (gravity flow)	Alternative 2 Exposed system of interceptor ditches	Alternative 3 Inclosed system of interceptor conduits in combination with storage and pumping
Technical			
Operation and maintenance problems	Very flat slope of interceptors may result in problems with accumulations of sediments in conduits in some areas.	Ice accumulations in open ditches during spring thaws sometimes result in greatly reduced flows during critical periods.	Operation and maintenance of 17 pumping stations and ponding areas will add significant burden to city utilities department.
Downstream flooding	Urbanization increases peak runoffs from an area. Potential exists for worsening existing downstream flood hazards. The extent of the effects of urban drainage on these downstream conditions is not yet determined.	Same as alternative 1.	Same as alternative 1. Ponding areas would reduce the rate of runoff.
Reliability	Capacity of existing major drainageways may limit discharges from interceptor systems during some periods, especially those interceptors discharging into legal drains and English Coulee floodway. Silting or clogging of the system may cause problems.	Same as alternative 1. Considered the most reliable system.	Same as alternative 1. Failure of pumping system may cause problems.

Table 15 - Summary of impacts of combined alternatives (Cont)

Impacts	Alternative 1 Inclosed system of interceptor conduits (gravity flow)	Alternative 2 Exposed system of interceptor ditches	Alternative 3 Inclosed system of interceptor conduits in combination with storage and pumping
Environmental			
Aquatic resources	Some minimal adverse impacts for channel improvements on upper reaches of English Coulee.	Same as alternative 1. May provide additional habitat.	Same as alternative 1. Will provide additional habitat.
Terrestrial Resources	No known effect.	Conversion of some terrestrial habitat to aquatic habitat.	Conversion of some terrestrial habitat to aquatic habitat.
Open space	No effect.	Public rights-of-way created along interceptor ditches.	Ponding areas must be preserved as open space.
Recreation	No effect.	Potential for trail development along ditch rights-of-way.	Ponding areas could be used for low density recreation. However, depth of ponding area imposes limitations on uses.

Table 15 - Summary of impacts of combined alternatives (Cont)

Impacts	Alternative 1 Inclosed system of interceptor conduits (gravity flow)	Alternative 2 Exposed system of interceptor ditches	Alternative 3 Inclosed system of interceptor conduits in combination with storage and pumping
Environmental (Cont)			
Natural streams	Possible degradation of English Coulee due to added stormwater runoff from urban areas. Conversion of 3 miles of natural intermittent streams to improved channels.	Same as alternative 1.	Same as alternative 1.
Water quality	Increase in urban runoff would reduce water quality of receiving stream.	Increased urban runoff. Channels could reduce sediment load and increase runoff water quality to receiving stream.	Increased urban runoff. Ponding would reduce sediment load and increase runoff water quality to receiving stream.
Sedimentation	Increase to receiving waters.	Minor.	Minor.

Table 15 - Summary of impacts of combined alternatives (Cont)

Impacts	Alternative 1 Inclosed system of interceptor conduits (gravity flow)	Alternative 2 Exposed system of interceptor ditches	Alternative 3 Inclosed system of interceptor conduits in combination with storage and pumping
Environmental (Cont)			
Aesthetics	Very minor effect. Majority of facilities would be subsurface.	Significant adverse effect. Over 25 miles of interceptor ditches within study area.	Minor effect.
Social			
Regional development	An adopted long-range urban drainage plan would have positive effects on systematic development of Grand Forks.	Same as alternative 1.	Same as alternative 1.
Community cohesion	No effect.	System of drainage ditches may become physical barriers that would adversely affect community cohesion.	No effect.
Convenience	Convenience increased by reducing ponding of stormwater on streets, parking lots, private property.	Same as alternative 1. Ditch system will have an adverse effect on local traffic patterns.	Same as alternative 1.

Table 15 - Summary of impacts of combined alternatives (Cont)

Impacts	Alternative 1 Inclosed system of interceptor conduits (gravity flow)	Alternative 2 Exposed system of interceptor ditches	Alternative 3 Inclosed system of interceptor conduits in combination with storage and pumping
Environmental (Cont)			
Nuisances	No effect.	If not properly maintained, low spots in ditches could develop and create small nuisance pools of trapped water.	If not properly designed and maintained, low spots in ponding areas could develop and create small nuisance pools of trapped water.
Safety	No effect.	Ditches can be a safety hazard during periods of high flow.	Ponding areas can be a safety hazard during periods of high flow.

CONCLUSIONS

On the basis of initial stage 2 analysis of urban drainage problems at Grand Forks, the following conclusions were reached:

a. Ditch alternatives are least costly. Possible adverse environmental and social impacts of the ditch alternatives may be greater than those of the other alternatives investigated. Ditches have the advantage of being adaptable to the flat topography in the Grand Forks area. Once ditch rights-of-way are established, it is fairly easy and economical to modify the system to accommodate changed conditions. This is an especially desirable feature in an area where future development is expected to occur. A ditch system has excellent capability for providing both a minor system of drainage for frequent runoff events and a major system for more infrequent events. A major problem with ditches is that ice jams occur during spring thaws and greatly reduce the effectiveness of the ditches during these periods.

b. Conduit alternatives without pumping or storage have the greatest economic cost and possibly the least adverse environmental and social impacts. To maintain gravity flow throughout the system requires close control of conduit slopes. The reasons are the flat terrain, limited depth of the receiving drainageways, and lengths of interceptor required. Limitations on slope result in larger conduits. The economic cost of the conduit alternative utilizing ponding and pumping is somewhat less than for conduits without these facilities, but the environmental and social impacts are somewhat more adverse. This alternative would result in development of numerous ponding areas and pumping stations that would require annual operation, maintenance, and replacement costs higher than the other alternatives considered.

c. Storage alternatives that show the most potential for implementation are swale development, street storage, and small temporary impoundments. Permanent impoundments are not desirable because of problems of maintaining permanent pool levels, costs of construction, and potential nuisance problems that can develop. Ponding areas incorporated in the interceptors are not particularly effective because of problems of achieving gravity flow into and out of the ponding areas.

d. With full urban development of the study area, the hydraulic capacity of the English Coulee floodway and the legal drains may be exceeded more often than is acceptable.

RECOMMENDATIONS

For this report the hydrologic impacts of urban runoff on the major existing drainageways were not determined. The impacts assessment only qualitatively identifies these effects. Future study should focus on routing flows through the watersheds to determine (1) the impact of urban runoff from the study area on the total system and (2) the capability of the drainageways to accommodate the estimated runoff from the study area. If the existing drainageways are not adequate, consideration should be given to necessary improvements.

Within the study area, local storage alternatives should be combined with the conduit interceptor alternatives. An optimum combination should be developed to reduce required conduit sizes, maintain gravity flow throughout the system, and reduce the impact of runoff. Storage alternatives should focus primarily on storage methods that can be incorporated into development plans and be implemented locally before surface runoff enters the publicly-owned drainage system.

After the combined alternatives are optimized, an overall drainage plan should be developed for implementation at the local level.

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STAGE 3 FLOOD CONTROL STUDIES

SUMMARY OF
STAGE 2 STUDY FINDINGS

GENERAL

Several structural and nonstructural solutions to floodplain management needs in the Grand Forks, North Dakota-East Grand Forks, Minnesota, area were addressed during stage 2 studies:

Nonstructural

- No further public action
- Flood warning and forecasting services
- Flood insurance
- Floodplain regulations and practices
- Evacuation/relocation
- Flood proofing
- Emergency flood fighting and relief activities

Structural

- Flood barriers
- Diversion of Red River of the North floodwaters around the west side of Grand Forks
- Reservoir storage
- Channel and bridge modifications
- English Coulee closure structure
- Diversion of Red River of the North or Red Lake River floodwaters around east side of East Grand Forks

The stage 2 plan formulation studies indicated that none of the nonstructural alternatives were feasible or viable alone. In many instances, however, they would be effective complements to flood barriers. Several measures (such as flood warning and forecasting, flood insurance, floodplain management regulations, and emergency flood fight measures) are

currently being used to prevent or reduce flood damages in the study area. The stage 2 formulation analyses suggested that, while permanently evacuating, relocating, or flood proofing the entire study area was not economically feasible, a combination of these measures might be feasible in Reaches 1 and 6.[1]

These studies also indicated that three structural measures merited further study:

1. Raising the existing Lincoln Park (Reach 2) levee/floodwall.
2. A closure structure across English Coulee (Reach 6).
3. Diverting Red Lake River floodwaters around East Grand Forks via Grand Marais Coulee.

During the April 1979 flood, it was feared that the wooden plank floodwall portion of the existing emergency flood barrier in Reach 5 (Riverside Park) might fail. A backup levee which excluded four homes was constructed to prevent flooding of the entire neighborhood in the event the floodwall failed. Subsequently, the four homes were flooded when a sewerline ruptured between the floodwall and backup levee. Local interests purchased the four homes to qualify for Federal assistance in removing them and constructing an earthen levee through their former sites to replace the wooden floodwall. The removal of these homes also resurrected interest in examining the economic feasibility of a permanent flood barrier along a new alignment in stage 3 of the urban study.

The record April 1979 flooding along English Coulee generated strong support for flood control measures along the coulee. In response to requests for permanent flood control measures, the city undertook design and construction of combined road raises and sewer modifications for two areas along the coulee. The Soil Conservation Service, Grand Forks County Water Management and Control Board, and city collaborated on alternative schemes for controlling and diverting runoff in the coulee's upper watershed. These schemes had to be taken into account by the Corps when formulating and evaluating stage 3 flood control alternatives.

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1 Descriptions of Reaches 1 through 6 are provided in the stage 2 report on floodplain management studies in Grand Forks.

Flood threats in the vicinity of Belmont Road in Reach 1 rekindled requests for permanent protection for this area. Of particular concern were areas along Belmont Road between 13th and 17th Avenues South, the Olson Drive-East Elmwood area, and the Terrace Drive area along Belmont Coulee. The city specifically requested evaluation of a closure structure near the mouth of the coulee.

PURPOSE AND SCOPE

The purpose of this stage 3 investigation was to formulate and evaluate in greater detail the alternatives recommended for further study plus the Riverside Park and Belmont Coulee closure structure alternatives. This study effort was intended to evaluate the economic feasibility of these alternatives and to provide a preliminary appraisal of the environmental and social well-being impacts attributable to each alternative.

PLAN FORMULATION

PLANNING OBJECTIVES

Two principal planning objectives were used to guide the formulation process: the national economic development objective and environmental quality objective. Specific local floodplain management planning objectives developed early in the stage 2 studies and further refined on the basis of the results of those studies include the following:

- Contribute to the reduction of recurring flood losses in the Grand Forks-East Grand Forks area to relieve the economic and psychological burdens on society and local residents during the 1980-2030 planning period.

- Contribute to the maintenance and enhancement of the environmental quality of riverine woodlands and wetlands in the study area to increase wildlife and recreational values during the 1980-2030 planning period.

- Contribute to development of a plan for effective floodplain management for the 1980-2030 planning period to ensure responsiveness to local desires, compatibility with other ongoing planning efforts, and acceptability to area residents.

- Contribute to the development of a flood emergency plan of action to ensure efficient local reaction to serious flood threats during the 1980-2030 planning period.

FORMULATION AND EVALUATION CRITERIA

Specific formulation and e luation criteria used in this study included economic, technical, environmental, and social well-being criteria.

Economic Criteria

- Tangible economic benefits of any selected plan must exceed related costs; i.e., a benefit-cost ratio exceeding unity.
- Annual costs and benefits are based on a 100-year economic life, a 6 7/8-percent interest rate, and August 1979 price levels.

Technical Criteria

- Where feasible, nonstructural measures are to be preferred over structural measures.
- All flood barriers and channel modifications will provide 3 and 2 feet of freeboard, respectively, over the design water surface profile.
- Where feasible, the flood barrier freeboard should contain the standard project flood flow or the maximum practical level of protection.
- Unstable riverbanks will not be overloaded or loaded in excess of acceptable design limits.
- For any flood proofing alternative, no structure will be flood proofed to a height greater than 3 feet if it is more than 100-feet riverward of the 100-year flood outline or if its first floor is more than 2 feet below the 100-year water surface elevation.
- Appropriate Corps engineering standards, regulations, and guidelines will be complied with.

Environmental Criteria

- Measures minimizing adverse environmental effects and maximizing environmental benefits before, during, and after construction will be developed and selected.
- Where feasible, the loss of riverine woodlands and/or wetlands and associated habitat will be minimized.

Social Well-Being Criteria

- The potential for loss of life and threats to public health and safety during flood periods should be minimized.
- Social, cultural, historic, and aesthetic values in the study area should be preserved and, where practical, enhanced.
- Any selected plan must be responsive to the desires of the community and be acceptable to the people.

ALTERNATIVES

On the basis of the recommendations of the stage 2 floodplain management studies and subsequent coordination with local interests, the following alternatives were selected for further study:

- Reach 1 - Combine flood proofing and evacuation in selected areas.
- Reach 1 - Place a closure structure/pumping station across Belmont Coulee.
- Reach 1 - Raise Belmont Road in the 13th to 17th Avenue South area.
- Reach 2 - Incease the level of protection of the existing Lincoln Park flood barrier.
- Reach 5 - Modify flood barrier types and alignments considered in stage 2 studies.
- Reach 6 - Construct a closure structure/pumping station near the mouth of English Coulee.
- Reach 6 - Combine flood proofing and evacuation in selected areas.
- Grand Marais Coulee diversion.

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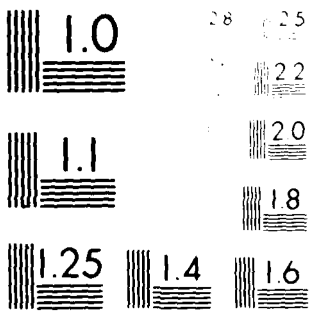
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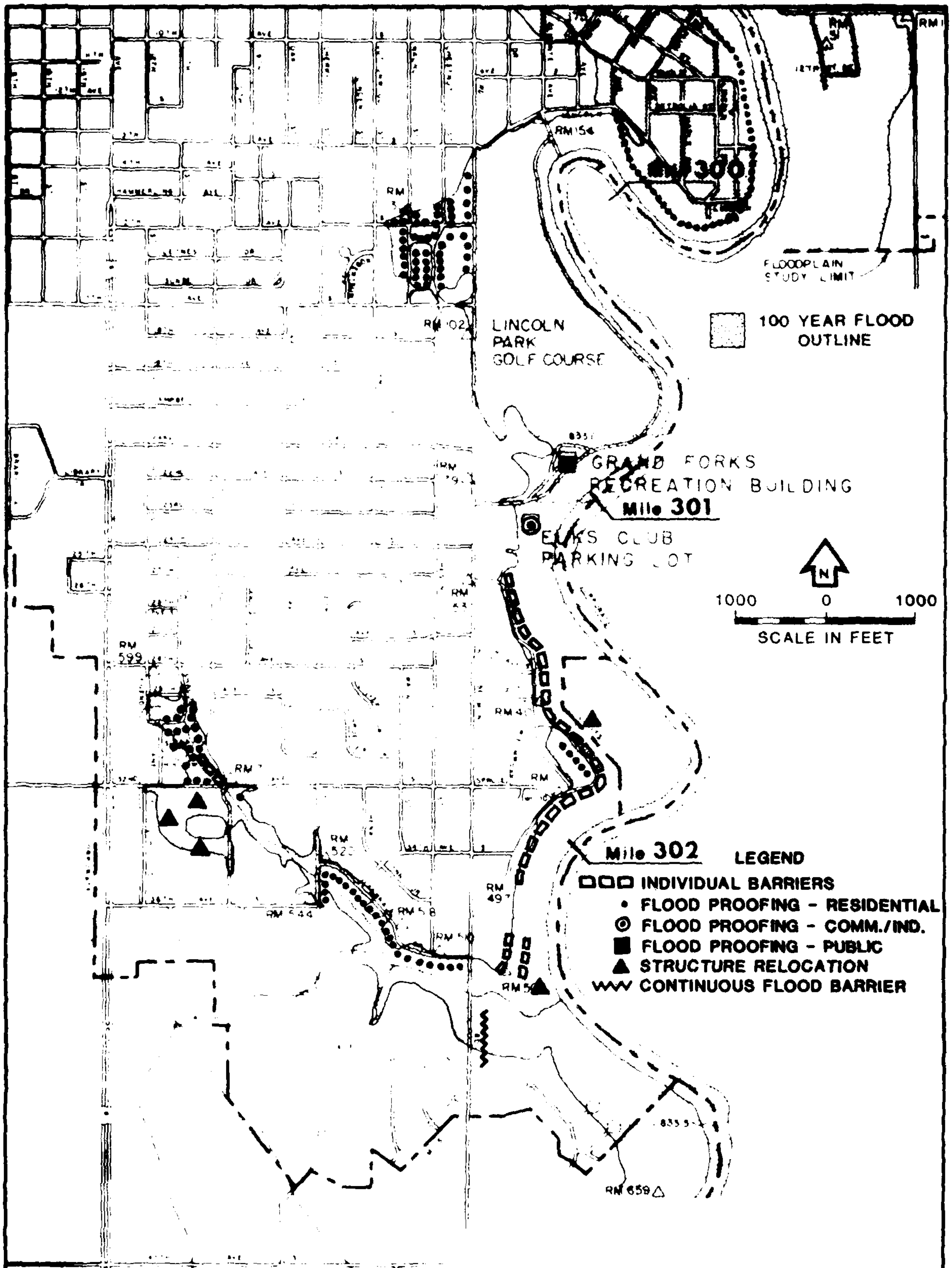
Reaches 1 and 6 - Combined Flood Proofing and Evacuation

The stage 2 studies indicated that flood proofing appeared to be the only practical solution for Reaches 1 and 6. Those same studies, while indicating that flood proofing alone would not provide economically feasible solutions for these reaches, did indicate that combined flood proofing and permanent evacuation proposals may be practical and economically feasible. Thus, this alternative provides for flood proofing of eligible structures in Reaches 1 and 6 together with the permanent relocation of ineligible structures located within the design floodplain.

The Reach 1 study area (figure 1) includes the 100-year floodplain along Belmont Coulee and along the Red River of the North between Almonte Avenue extended (at the north end of Lincoln Park) and the southerly city limits. In the 100-year Reach 1 floodplain are 256 residences, 1 commercial-industrial structure, and 2 public structures that could be flood proofed. The study area for English Coulee includes the 100-year floodplain extending from Mill Road upstream to 32nd Avenue South as shown on figure 2. Approximately 358 homes, 15 commercial-industrial structures, and 11 public structures are located within the 100-year English Coulee floodplain.

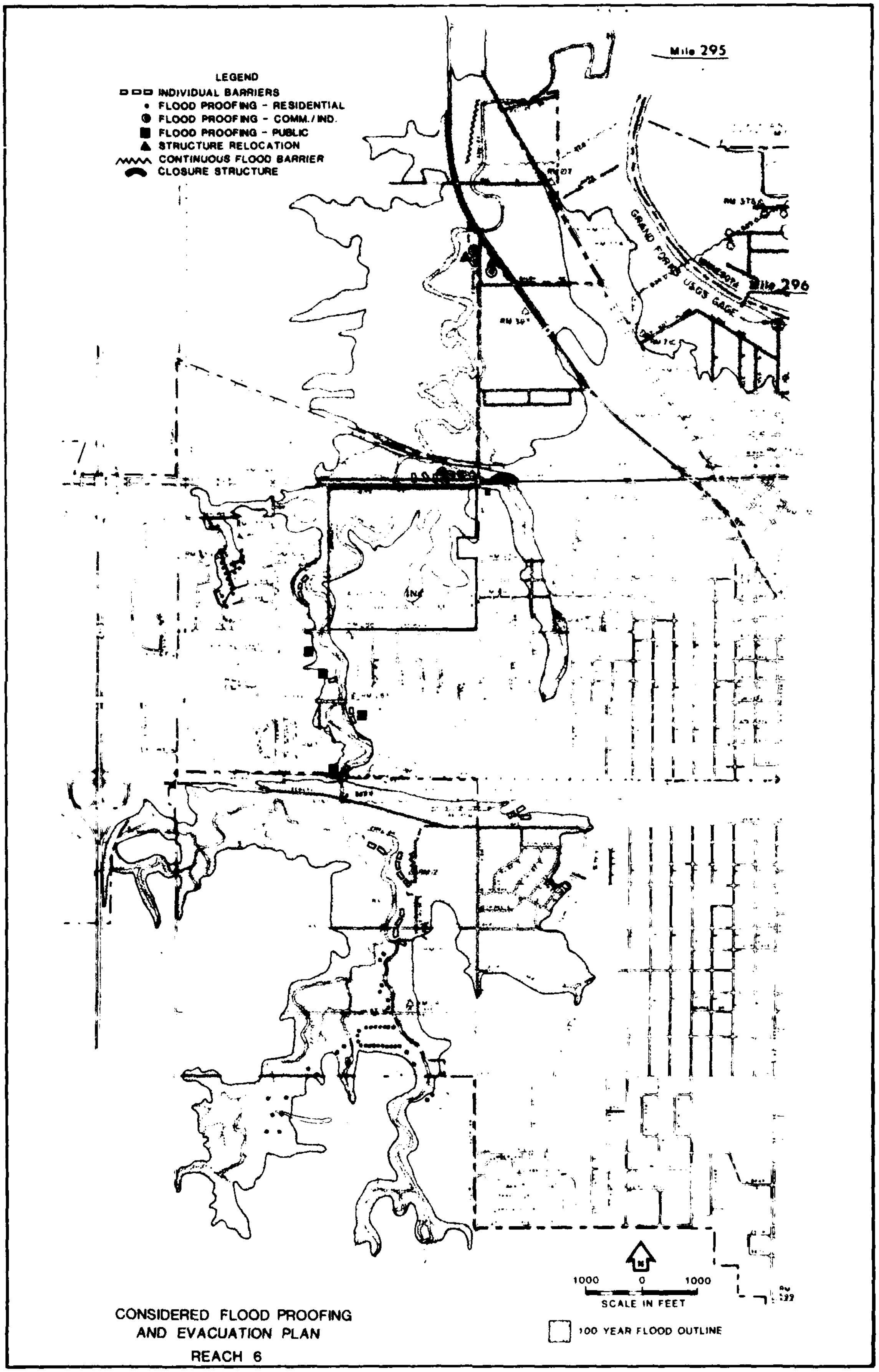
In general, any structure not more than 100 feet within the design flood outline and/or having a first floor elevation not more than 2 feet below the design water surface elevation was considered for flood proofing. Structures not meeting these criteria would either be relocated to a flood-free site or razed depending on type and physical condition.

Although most simply and economically incorporated into new construction, flood proofing is in many instances applicable to existing development. Flood proofing as considered in this analysis includes measures such as low barriers to protect small clusters of structures and various measures to protect individual structures. Individual residences would be flood proofed by either permanent or temporary sealing of low-level window, door, and other openings; installing floor drain standpipes and/or check valves; and, where



CONSIDERED FLOOD PROOFING AND EVACUATION PLAN REACH 1

FIGURE 1



CONSIDERED FLOOD PROOFING
AND EVACUATION PLAN
REACH 6

FIGURE 2

practical, constructing low barriers to protect walkout basement levels. Relocation of utilities and other equipment to flood-free levels within the structure was considered in some instances.

Commercial, industrial, and public structures would be flood proofed with either fixed or movable bulkheads across low-level window, door, and other openings depending on building use requirements; reinforcing and waterproofing of masonry walls where practical; and modification of depressed loading ramps where feasible. Along English Coulee, a cluster of commercial structures along U.S. Highway 81 would be better protected by a flood barrier rather than individual structure measures. In other instances, low earth berms or concrete walls around individual structures would be more cost effective. In a few instances and for the smaller structures, raising the structure on fill would be effective. Figure 2 is a map showing the approximate location and general type of flood proofing or evacuation measures considered for Reach 6.

The city of Grand Forks is investigating flood damage reduction measures along English Coulee. The city recently raised South 30th Street from 11th Avenue South to 14th Avenue South and installed flapgates on two storm sewer lines. These measures, with an appropriate temporary sandbag or earthen closure across DeMers Avenue, would provide a 100-year level of protection (without freeboard) to the area east of South 30th Street.

The city has also provided closure devices at two existing culverts through Columbia Road just north of U.S. Highway 2. Closure of these culverts will prevent floodwater backup into the residential area south of 10th Avenue North. However, these measures would provide only a 50-year level of protection.

Measures under consideration by the city for Reach 1 (see figure 1) include creation of a flood assessment district for the flood-prone area between 13th and 17th Avenues South along Belmont Road and a closure structure at the Belmont Road crossing of Belmont Coulee. The district would provide for assessment of affected residents to meet the costs of emergency flood barriers along Belmont Road together with required temporary interior drainage pumping. Both measures, assuming the temporary

measures are effective, would eliminate the need for flood proofing.

Estimated first costs for flood proofing were determined in accordance with procedures outlined in the Corps of Engineers' publication "Estimating Costs and Benefits for Nonstructural Flood Control Measures," dated October 1975. Other useful cost and benefit data were obtained from the Corps of Engineers' publication "Physical and Economic Feasibility of Nonstructural Floodplain Management Measures," dated March 1978. Levee and floodwall costs were determined using prevailing material and labor costs.

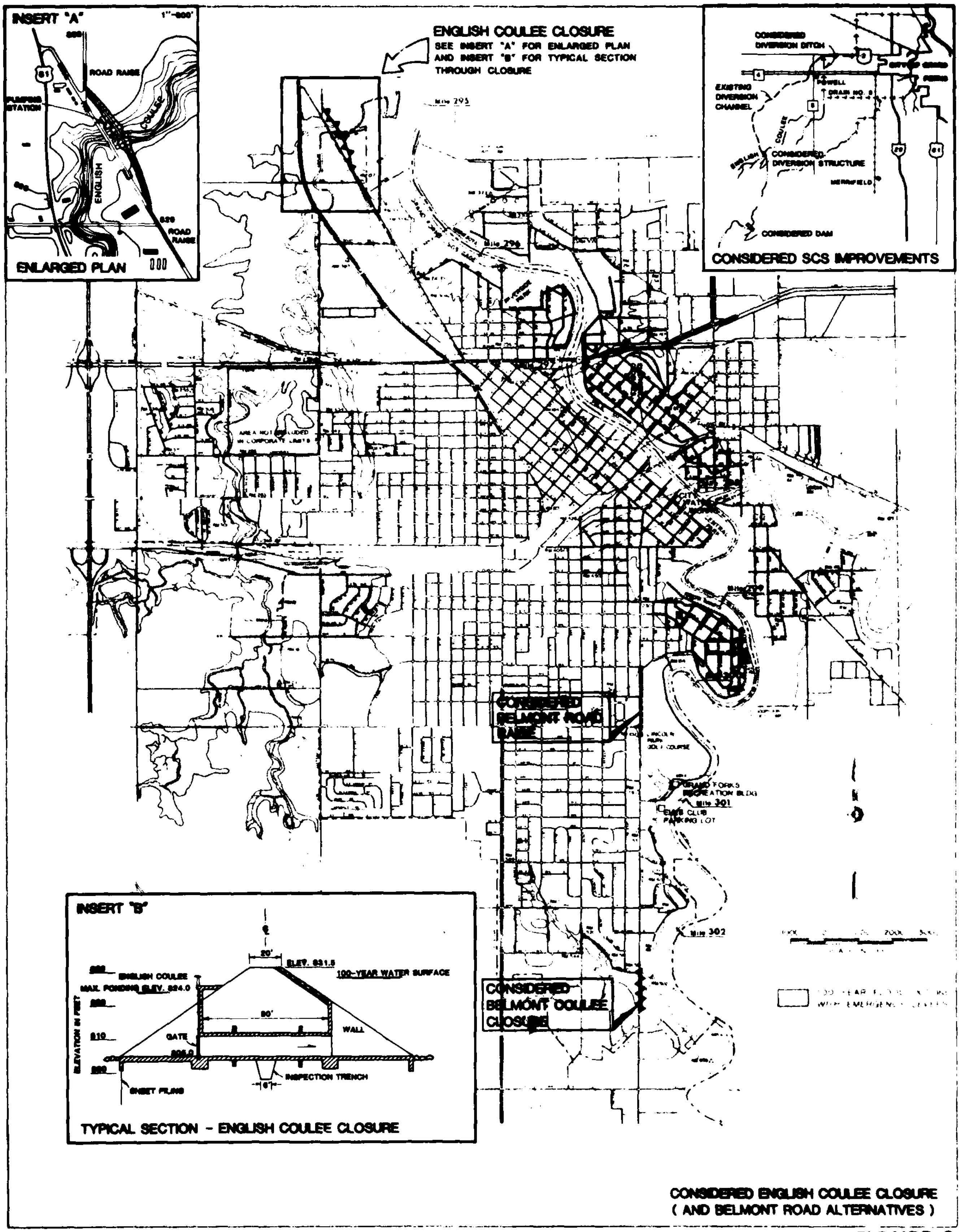
Estimated total 100-year plan first costs for Reach 6 flood proofing and evacuation (see figure 2) would be $1,180,000. Total first costs for the considered Reach 1 measures shown on figure 1 would be $2,596,000.

Reach 1 - Belmont Coulee Closure

About 5 years ago, the North Dakota State Water Commission prepared designs and cost estimates for a closure structure across Belmont Coulee at Belmont Road. This structure (see figure 3) was designed to prevent 100-year Red River floodwaters from entering the coulee. With this plan, the existing road embankment would be modified to serve as the closure. A 72-inch flapgated culvert would pass normal flows through the barrier. A pumping station consisting of four 15,000 gpm (gallon per minute) pumps would pass interior runoff from the coulee during floods. Two 42-inch RCP (reinforced concrete pipe) gated culverts would discharge pumped flows through the barrier. The stage 3 analysis considered this same proposal in response to renewed interest by the city.

Reach 1 - Belmont Road Raise

Also in response to concerns expressed by the city during stage 3 studies, a raise of Belmont Road between 13th and 17th Avenues South was considered (see figure 3). The maximum practical level of protection



CONSIDERED ENGLISH COULEE CLOSURE
(AND BELMONT ROAD ALTERNATIVES)

FIGURE 3

was determined to be about the 50-year level or an elevation of about 830.0. The maximum raise would be about 3 feet (at 15th Avenue South). The total length of road raise would be about 1,160 feet.

Reach 2 - Lincoln Park Flood Barrier Raise

The existing federally-constructed flood control project in Reach 2 consists of a 5,160-foot earthen levee with an average top height of 14 feet, a 770-foot reinforced concrete floodwall, and interior drainage works including a 21,720-gpm pumping station as shown on figure 4. The levee has a 10-foot top width and 2.5 horizontal to 1.0 vertical side slopes. The project was designed to protect the Lincoln Park residential area from a 79,000-cfs or 50-year Red River of the North flow with 2 feet of freeboard.

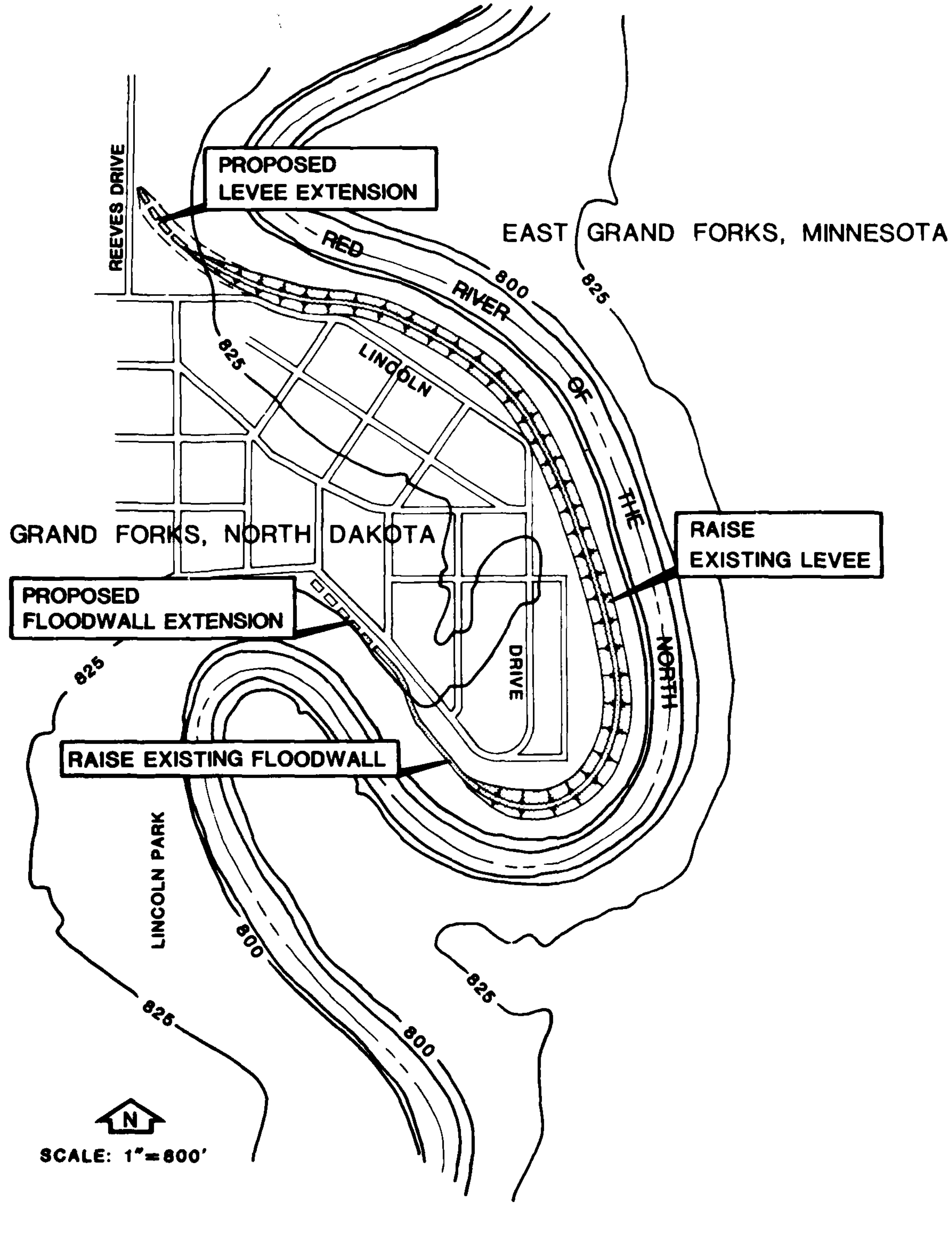
The 79,000 cfs flow was the maximum flood of record when the project was constructed in 1958. On the basis of current hydrologic and updated hydraulic data, the average top elevation of the flood barrier is approximately equivalent to a 50-foot stage at the Grand Forks gage (gage zero - 778.35, 1929 adj.) or a 1.25-percent chance (80-year) flood height. With 3 feet of freeboard, the levee provides a 30-year level of protection.

Local interests are interested in upgrading the Reach 2 flood barrier to provide a higher level of protection. The completed stage 2 studies considered a 3.6-foot vertical raise of the existing 5,160-foot levee together with a 1,480-foot floodwall extending upstream from the existing 770-foot floodwall, increased capacity of the interior drainage pumping station, and the removal of 18 homes along the new floodwall alignment. The considered 1,480-foot floodwall was designed to connect with considered Reach 1 flood barrier measures. For the stage 2 plan, removal of the 18 homes was considered necessary to provide a practical and technically feasible floodwall alignment. Provision of a floodwall riverward of the homes would require a very high floodwall along an unstable riverbank area.

In the Grand Forks area, 100-year protection depends on the availability of sufficient high ground elevation for flood barrier tiebacks. The stage 2 studies used project document data from the existing Corps project for the considered levee raise together with U.S. Geological Survey topographic data for the 1,480-foot floodwall extension. Using this data base, the stage 2 studies indicated that the considered 100-year Reach 2 modifications would be economically infeasible as indicated by the 0.34 benefit-cost ratio. However, these same studies indicated, based on the limited available engineering data, that a 50-year level of protection would be marginally feasible. Thus, it was recommended that the study results be reviewed in stage 3 using more detailed field topographic and foundations data together with consideration of benefits resulting from the reduction of future flood damages. Peak floodwater stages during the April 1979 flood reached the crest of the existing levee at two locations, further emphasizing the need for modifications.

Thus, on the basis of more detailed topographic, soils and economic data and desires of local interests, this stage 3 analysis also considered raising and extending the existing flood barrier. Raising of the barrier to provide either a 50- or 100-year level of protection with 3 feet of allowable freeboard was initially considered.

However, subsequent field topographic surveys demonstrated that high ground elevations are not available at either end of the existing flood barrier to achieve either level of protection. These surveys revealed that the maximum available tieback elevation at the north or downstream end of the existing levee would be elevation 832.8 (1929 adj.), about 1.8 feet above the average top elevation of the existing levee, but only 1.1 feet above the 100-year flood level and 3.4 feet above the 50-year flood level. Similarly, the maximum available tieback elevation at the upstream end of the existing floodwall is 832.5, about 0.3 foot above the 100-year water surface elevation and 2.6 feet above the 50-year flood level. Thus, neither level of protection with 3 feet of freeboard can be attained; the maximum practical level of protection is approximately



CONSIDERED REACH 2 FLOOD BARRIER RAISE

FIGURE 4

47 years (2.15 percent) with 3 feet of freeboard. Current Corps standards regarding the minimum level of protection for structural measures in urban areas preclude Federal participation at less than a 100-year level of protection. Therefore, permanently raising the Lincoln Park flood barrier to its maximum 47-year level of protection could not be done with Corps assistance. Prior Corps approval for a locally-sponsored barrier raise would be needed to ensure that the integrity of the Federal project would not be compromised by the raise. For instance, the potential aggravation of unstable foundation conditions would have to be thoroughly investigated.

Flood barrier extensions of 640 and 300 feet would be required at the upstream and downstream ends, respectively, to achieve the 47-year level of protection based on the controlling tieback elevations. Average heights of these barriers would be about 1.0 and 4.0 feet, respectively. Provision of these extensions would require removal of 2 homes and landscape modifications at 10 other residences. Only minor additional collector works would be required to control interior runoff from the additional protected area. Total estimated first costs for raising the existing flood barrier to the maximum practical (47-year) level together with the considered levee and floodwall extensions as shown on figure 4 would be $387,000.

Reach 5 - Flood Barrier Modifications

The stage 2 studies considered a system of flood barriers consisting of levees, floodwalls, and closure structures between U.S. Highway 2 on the south end and Mill Road on the north end. The 100-year system provided for a 2,260-foot floodwall (8)[1] with an average height of 11.6 feet extending northward from the U.S. Highway 2 embankment along the existing emergency flood barrier alignment, a 520-foot levee (9) along the existing levee alignment between Riverside Drive and Lewis Boulevard, a 1,250-foot levee (10) along the existing levee alignment between Lewis Boulevard and North 2nd Street, an 800-foot levee (11) with an average height of 8 feet extending northwesterly across the park between North 2nd Street and North 3rd Street, a 600-foot levee (12) from North 3rd Street at the west edge of the park

[1] See figure 5 for location of flood barriers.

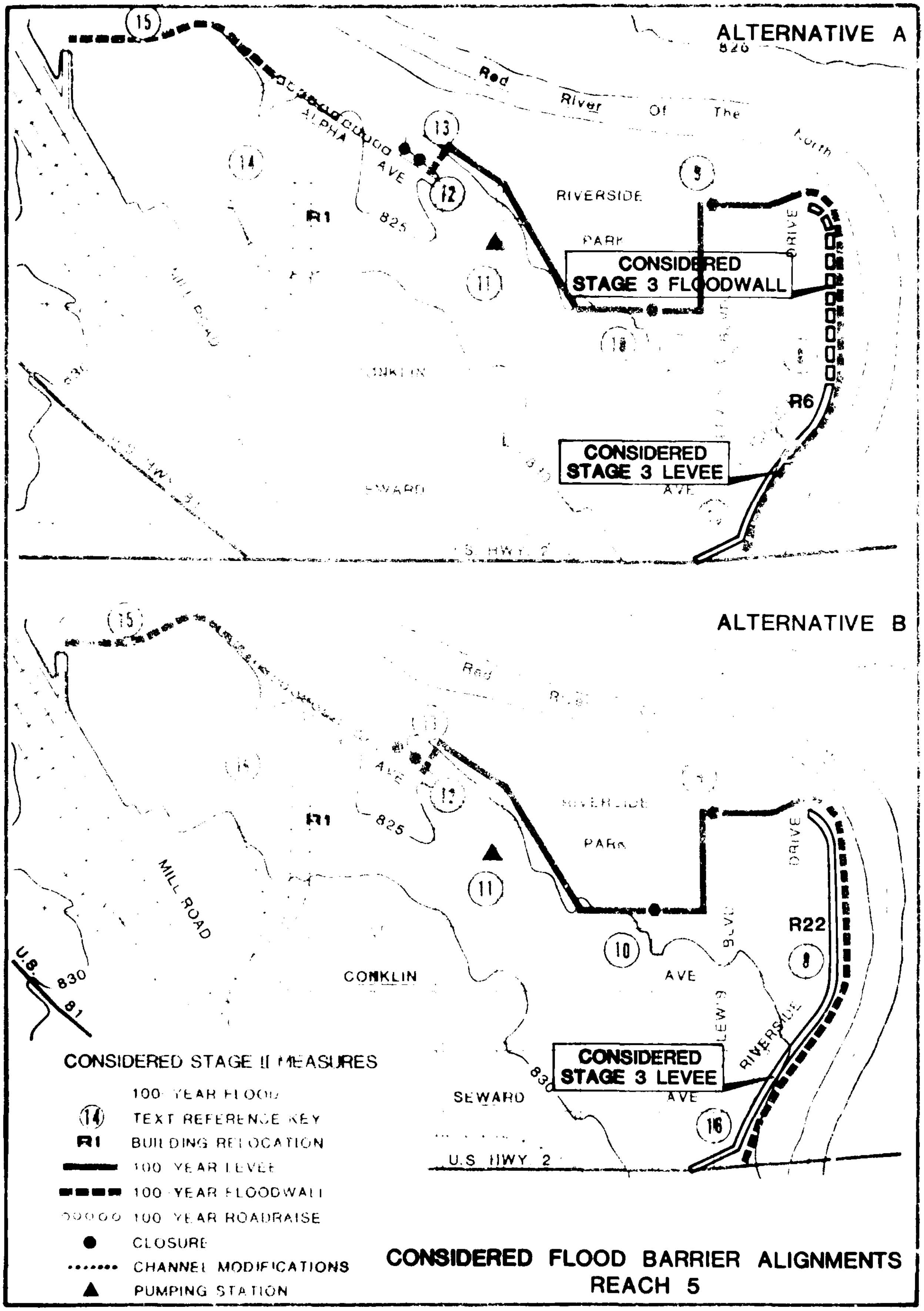
extending westerly along high ground, thence a 400-foot floodwall (13) extending southward to Alpha Avenue, an 800-foot raise of Alpha Avenue (14), and a 1,400-foot floodwall (15) with an average height of 5 feet between Alpha Avenue and North 20th Street as shown on figure 5.

Related measures considered in the stage 2 studies included the conversion of 300 feet of local street between U.S. 2 and Seward Avenue to flood barrier right-of-way (16) and the relocation of 200 feet of Riverside Drive north of Seward Avenue. Four closure structures were considered at three locations. Ten homes, nine between U.S. Highway 2 and Riverside Drive (along flood barrier segment 8) would be relocated. Proposed interior drainage measures included a 48,400-gpm pumping station and attendant collection works. Total first costs for these improvements at August 1979 price levels are estimated at $6,109,000.

During the April 1979 flood, it quickly became evident that the existing emergency timber floodwall near Seward Avenue was unstable and permitting excessive leakage through and under the barrier. To preclude extensive damages resulting from a sudden failure, the city decided to construct a second barrier landward along Riverside Drive. This action ultimately prevented serious flooding in the Riverside Park neighborhood after a sewer break flooded the area outside the backup barrier, but unfortunately flooded four residences between the backup barrier and the emergency floodwall.

Because local consideration was being given to the acquisition of these four residences, it was considered advisable in these stage 3 studies to reinvestigate the feasibility of Reach 5 measures using levees or a combined levee-floodwall in lieu of the 2,260-foot floodwall considered in stage 2. Two alternatives to the 2,260-foot floodwall were considered:

1. A 1,570-foot levee from the U.S. Highway 2 embankment northward to about Conklin Avenue and a 1,060-foot floodwall from Conklin Avenue northward along Riverside Drive as shown on figure 5 as Alternative A. This barrier would require the relocation of six homes including the four homes flooded in April 1979.



CONSIDERED FLOOD BARRIER ALIGNMENTS
REACH 5

FIGURE 5

2. A levee in lieu of the 2,260-foot floodwall with the removal of 22 homes or all homes riverward of Riverside Drive (see Alternative B on figure 5).

The removal of homes for both alternatives is dictated by the necessity to relocate the flood barriers landward of the unstable riverbank along this reach.

Reach 5 interior drainage needs were reanalyzed. A 24,800-gpm pumping station would be required with a 100-year level of protection in lieu of the 48,400-gpm pumping station considered in stage 2. This reduction in capacity together with resizing of required collector facilities would result in reduced Reach 5 interior drainage costs of about $975,000 from the updated stage 2 cost estimate.

Both barrier modifications would significantly reduce total stage 2 plan first costs. A combined floodwall and levee in lieu of the 2,260-foot floodwall would reduce total Reach 5 first costs by about $2,466,000 for a 100-year level of protection. A levee, together with the acquisition and removal of 22 homes, would reduce the total updated stage 2 100-year first costs by about $1,642,000.

Reach 6 - English Coulee Closure

Recurrent flooding and related damages occur along English Coulee (see figure 3) from two sources. The principal flood problem is caused by backwater from the Red River. At the 100-year flood level of 829.0, Red River floodwaters will back up approximately 5.5 miles along the coulee or to the vicinity of DeMers Avenue. Spring flood problems associated with this backwater may be aggravated by snowmelt and rainfall runoff from the English Coulee drainage basin. This situation occurred during the April 1979 flood. Severe flood problems along the coulee may also be caused by heavy summer thunderstorms and related rapid runoff through the coulee. However, summer floods do not occur as frequently as floods caused by backup of Red River floodwaters.

Flood damages along the coulee occur mostly to residential development with minor damages to commercial, industrial, and public development. Much of the residential damage is attributable to older development with walkout basements at about the 25-year flood level and other structures in the 100-year floodplain. Most of the recent development is constructed with first floors above the accepted 100-year flood level. Much of the flood-prone commercial development, located for the most part north of U.S. Highway 2, is also in the 25- to 100-year flood level. Public developments, principally structures at the University of North Dakota and located close to the coulee, are affected by floodwaters entering low-lying walkout levels and utility tunnels.

Planning efforts by the city of Grand Forks, other local agencies, the North Dakota State Water Commission, and the U.S. Soil Conservation Service to reduce flood damages along the coulee have continued for several years. Completed work includes a channel to divert a portion of coulee flood flows around the northwest part of Grand Forks. However, the structure required to divert the flood flows from the coulee has not been built. Further, the capacity of the channel is limited by inadequate culvert capacity at the U.S. Highway 2 crossing west of Grand Forks. With adequate culvert capacity and the diversion structure in place, the diversion works would divert 600 cfs (cubic feet per second) or 26 percent of the 100-year 2,300-cfs flood flow away from the urbanized reaches of the coulee.

Recent planning efforts by local agencies and the Soil Conservation Service have identified additional possible flood damage reduction measures which are presently being studied. These measures include a dry dam to control runoff from 57 square miles of the 106-square-mile drainage area (as measured at Mill Road) and the additional diversion of coulee flows from Legal Drain 9 northward to the existing diversion channel as shown on the inset map on figure 3. With the proposed diversion structure and dam in place, an uncontrolled downstream drainage area of 36.8 square miles between the point of diversion and the considered closure site would remain. With the considered additional downstream diversion from Legal Drain 9, this drainage area would be reduced to about 28.6 square miles.

The formulation of this alternative is based on two alternate assumptions: (1) the considered dam and two diversion measures would be in place and (2) only the considered dam and proposed upstream diversion structure would be completed prior to any closure measures. Inclusion of the dam in both alternatives is considered essential because pumping requirements for uncontrolled peak 100-year flows from the entire English Coulee drainage area would be prohibitively expensive. The second assumption appears to be the most probable near-term course of action if the dam is technically and economically feasible.

Assuming that the Soil Conservation Service dam and upstream diversion works were in place, the peak 100- and 50-year flood flows would be 1,970 and 1,620 cfs, respectively, at the closure structure site during a summer flood. For a combined spring snowmelt and rainfall runoff occurring over a longer period, these flows would be approximately 1,560 and 1,290 cfs, respectively. With the additional Legal Drain 9 diversion in place, the peak spring and summer 100-year flood flows through the urbanized area would be about 1,310 and 1,650 cfs, respectively, and 1,070 and 1,350 cfs, respectively, for the 50-year flood. With only the existing diversion channel in place providing a peak 100-year diversion of 600 cfs, the peak 100-year flood flows for the spring and summer flood occurrences would be approxmately 1,760 and 2,370, respectively.

Even with the dry dam and diversion in place, additional measures would be required to reduce flood damages along the urbanized reach of the coulee. These additional measures would include an operable closure structure across the coulee to prevent backup of Red River floodwaters and an interior drainage pumping station at the closure site to pass coulee flows in excess of ponding capacity during Red River flood stages. Also included would be the designation of the lower coulee reach from Sixth Avenue North to the closure site as a temporary floodwater storage area. The maximum ponding elevation would be 824.0 which would be about 1 foot below the lowest structure elevation.

The closure structure gates would be sized to pass a spring or summer flood flow from either the 28.6- or 36.8-square-mile drainage areas without exceeding the maximum allowable ponding elevation provided that the dam was operational and that no coincidental high stages occurred on the Red River. A 506,000-gpm pumping station would be required to pass these same flows during main stem flooding.

The closure structure would be immediately downstream of Mill Road as shown on figure 3. The structure would be 2,000 feet long excluding 1,300 lineal feet of road raise (average height = 1.5 feet), have a top elevation of 831.5,[1] and include two 6-foot by 6-foot by 80-foot long gated culverts. A typical section through the structure is also shown on figure 3. The pumping station on the upstream control structure embankment would have 506,000-gpm capacity to pass excess 100-year flows from a spring flood from the 28.6-square-mile drainage area. The maximum ponding level along the coulee between the structure and Sixth Avenue North would be elevation 824.0 to preclude flood damages to walk-out level basements along the reach. Also included would be the flap gating of two 42-inch storm sewers entering the coulee storage area. Total first costs for a 100-year level of protection (excluding costs for the dam and diversion works) are estimated at about $1,351,000.

Grand Marais Coulee Diversion

Grand Marais Coulee begins near the Red Lake River at Fisher, Minnesota, and extends northwesterly 23 valley miles to its intersection with the Red River 10 miles downstream of the Grand Forks-East Grand Forks area as shown on figure 6. The coulee, with a total drainage area of 275 square miles, has a meandering drainage course with a total channel length of 42.4 miles. Typical channel width and depth upstream of road crossings are about 220 and 6 feet, respectively. The average channel width is roughly 150 feet. The channel is crossed by 28 bridges and culverts. Numerous drainage ditches enter the coulee.

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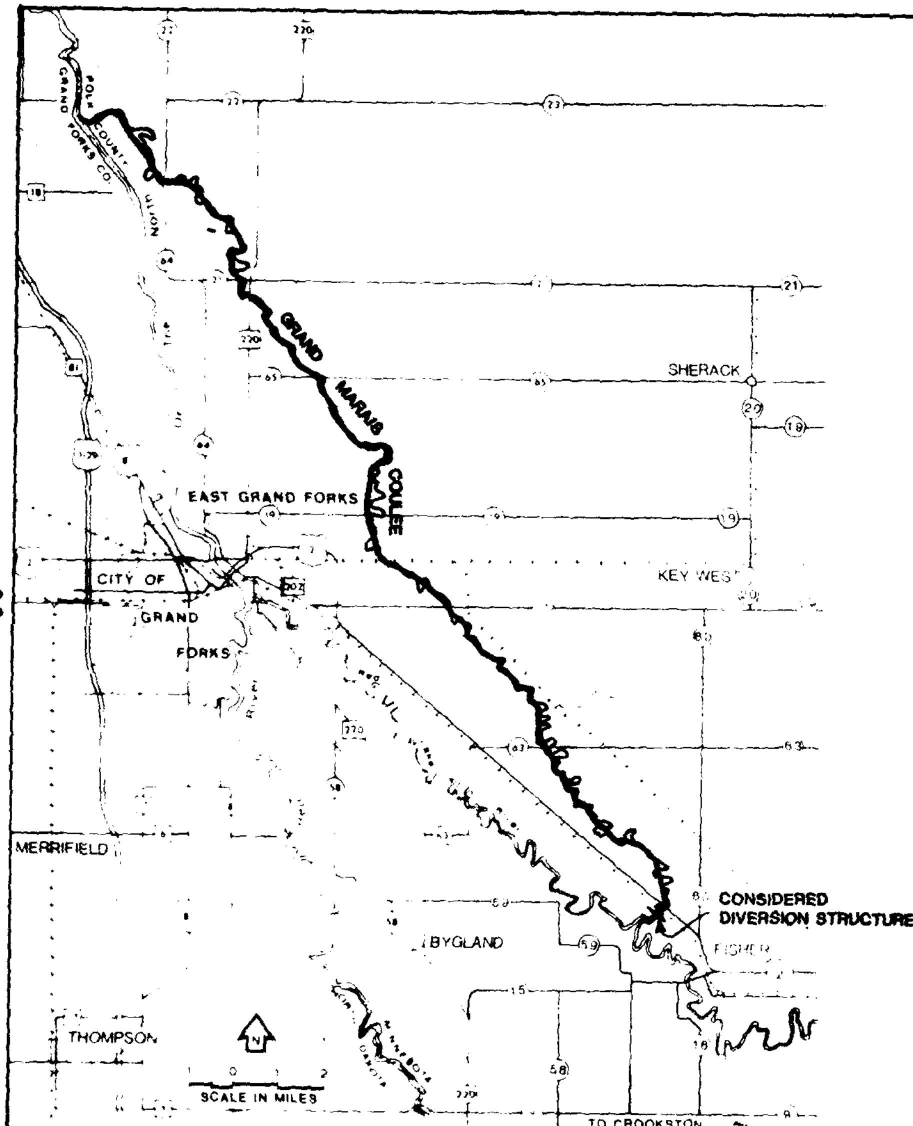
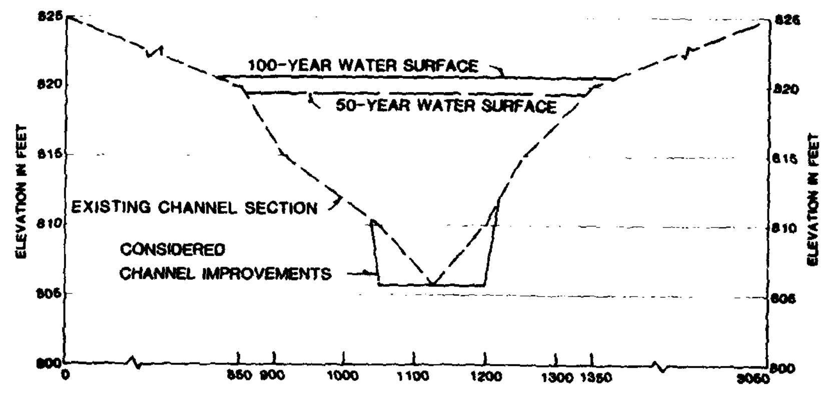
[1] Providing 2.5 feet of freeboard above the 100-year design flood level. Lack of sufficiently high ground within practical reach of the closure location prevents 3 feet of freeboard.





TYPICAL SECTION

CONSIDERED GRAND MARAIS COULEE
CHANNEL IMPROVEMENTS

FIGURE 6

Land use along the coulee is entirely agricultural and is separated from the coulee by narrow intermittent strips of riverine woodlands, wetlands, and/or pasture. Numerous small slack-water pools are located along the coulee downstream of the U.S. Highway 2 crossing. Flows vary from little or no flow during the late summer to winter months to an estimated 3,540 cfs during a 100-year flood at the U.S. Highway 220 bridge crossing north of East Grand Forks.

The coulee supports a variety of small mammals, amphibians, and waterfowl. Beaver are present along the lower reaches. Several species of ducks use the pool areas for nesting and resting. Small fish, presumably rough fish, were recently (August 1979) observed in some of the pools.

Under nonflood conditions, the coulee drains a 275-square-mile drainage area. However, high flows on the Red Lake River overflow and enter the coulee at a point about 4 miles downstream of Fisher. Recent field surveys indicate that these overflows begin at a river stage of about 830.5 which roughly corresponds to a 13,000-cfs discharge (5-year frequency flow) on the Red Lake River.

The considered plan of improvement would provide for diversion of a maximum of 50 percent of the peak design Red Lake River flood flow in excess of 13,000 cfs or about 10,500 cfs,[1] for the 100-year design condition. To accomplish this diversion, a fixed crest spillway approximately 600 feet long would be provided at the existing overflow point as shown on figure 6.

Knowing that Red Lake River overflows do at times enter the coulee, local interests have suggested using the coulee, unimproved or improved, to pass a designated portion of Red Lake River overflows, which in turn would reduce flood stages and related damages in the Grand Forks-East Grand Forks areas. Computerized hydraulic studies made in support of these studies indicate an existing bankfull channel or zero damage capacity of about 2,950 cfs. The channel capacity is severely restricted by the numerous small bridge and culvert openings and scattered areas of trees, shrubs, and cattails in the channel. Preliminary studies indicate that

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[1] (34,000 cfs - 13,000 cfs)/2.

an improved channel with a 150-foot bottom width and with all bridges sized to the channel cross section and areas of heavy shrubs and trees removed would have a bank-full capacity of about 7,500 cfs.

Peak flood flows greater than 7,500 cfs would exceed bank-full capacity with resultant inundation and damages to several adjacent farmsteads. Thus, the provision of additional overflows from the Red Lake River without substantial channel widening and bridge modifications would greatly aggravate the local flood situation along the coulee.

To pass a maximum 100-year diversion of 10,500 cfs plus the 100-year flow from the coulee drainage area itself would require an improved channel with a 200-foot bottom width together with numerous cutoffs as shown on figure 6. Also required would be the replacement of 12 highway bridges and 1 railroad bridge. Total first costs for this plan are estimated at $36,314,000.

IMPACT ASSESSMENT

The following paragraphs discuss the principal economic, environmental, and social well-being impacts of the considered alternatives. Tables summarizing pertinent economic data for each alternative are included.

REACH 1 - COMBINED FLOOD PROOFING AND EVACUATION

The considered 100-year flood proofing and evacuation measures would cost nearly $2.6 million (table 1) to protect about 200 structures. Present cost-sharing arrangements result in total Federal and non-Federal first costs of about $2,077,000 and $519,000, respectively, with 80-percent Federal cost sharing as shown on table 2. These measures would reduce average annual damages by about $45,000. Total average annual benefits including an allowance for reduction of future flood damages to residential contents would be about $58,000 (see Attachment A for details of the benefit analyses). A comparison of these benefits with related average annual costs of $182,900 yields an unfavorable benefit-cost ratio of 0.3 (table 3).

Table 1 - Reach 1 - flood proofing and evacuation first costs

Item	Costs for different levels of protection 4%(25-year)	2%(50-year)	1%(100-year)
Localized flood barriers[1]	$4,000	$127,000	$1,401,000
Structure relocations	0	0	21,000
Structure raises	0	0	0
Flood proofing commercial bldgs.	0	0	1,000
Flood proofing public bldgs.	0	0	0
Flood proofing, residences	13,000	43,000	103,000
Structure purchases	0	205,000	729,000
Lands and rights-of-way	0	0	2,000
Total construction[2]	17,000	375,000	2,257,000
Engineering, design, supervision, and administration[3]	3,000	56,000	339,000
Total first costs	20,000	431,000	2,596,000

1 Includes individual barriers around basement walkouts.
2 Includes 25% for contingencies.
3 15% of total construction cost.

Table 2 - Reach 1 - flood proofing and evacuation cost sharing

Item	Costs for different levels of protection 4%(25-year)	2%(50-year)	1%(100-year)
Present cost-sharing policy:			
Federal (80% of first costs)	$16,000	$345,000	$2,077,000
State (None)	0	0	0
Local (20% of first costs)	4,000	86,000	519,000
Total first costs	20,000	431,000	2,596,000
President's proposed policy:			
Federal (75% of first costs)	15,000	323,000	1,947,000
State (5% of first costs)	1,000	22,000	130,000
Local (20% of first costs)	4,000	86,000	519,000
Total first costs	20,000	431,000	2,596,000

Table 3 - Reach 1 - flood proofing and evacuation benefit-cost analyses

Item	Benefit-cost data for different levels of protection		
	4%(25-year)	2%(50-year)	1%(100-year)
Federal annual costs[1]	$1,100	$23,700	$143,000
Non-Federal annual costs[1]	600	8,100	39,900
Total annual costs	1,700	31,800	182,900
Total average annual benefits	12,000	31,000	58,000
Benefit-cost ratio	7.1	0.97	0.3
Net average annual benefits (nearest $1,000)	10,000	-1,000	-125,000

[1] On the basis of the present cost-sharing policy, 6 7/8-percent interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance.

Protection of 74 structures from the 50-year flood is nearly economically justified (with a benefit-cost ratio of 0.97). At the 25-year level of protection, the benefit-cost ratio is greater than 7; however, the number of homes that would be protected is only 19.

The considered measures would have only minor long-term adverse environmental impacts in the immediate vicinity of the considered flood barriers because the required construction areas are presently developed lawns or paved areas generally devoid of natural cover. The measures would provide a beneficial long-term social well-being impact through reduced average annual flood damages. Depending on the level of protection, the permanent removal of several homes from the floodplain (12 with the 100-year plan) could constitute a moderate short-term adverse impact. A relatively minor long-term adverse social impact would result from obstruction of riverfront views from walkout levels along Terrace Drive and the Red River.

REACH 1 - BELMONT COULEE CLOSURE

The considered closure works would prevent backup of Red River floodwaters into the coulee west of Belmont Road. Approximately 55 residential structures would be protected against a 100-year flood level. The considered measures would result in relatively minor landscape changes because the control structure and pumping works would be largely incorporated within an existing road embankment that would be raised a maximum of 6.3 feet. The considered measures would result in total first costs of $692,000, all of which would be Federal costs according to the present cost-sharing policy (table 4). Average annual costs (including allowance for annual operation, maintenance, and periodic equipment replacement) are estimated at $50,000 (table 5). Corresponding average annual benefits are estimated at $25,000, yielding a benefit-cost ratio of 0.5.

REACH 1 - BELMONT ROAD RAISE

The considered road raise would prevent Red River flood overflows (50-year maximum practical level with 1 foot of freeboard) into a single-family residential area. About 50 homes would be protected. The proposed road raise would require the relocation of the existing sanitary sewer lift station at 15th Avenue South. It would also result in the need for raising 13 driveway approaches and the 15th Avenue South intersection. Total first costs are presently estimated at $284,000 (table 6). Related average annual costs are estimated at $19,800 (table 7). Corresponding average annual benefits are estimated at $10,000, yielding a benefit-cost ratio of 0.5.

REACH 2 - FLOOD BARRIER RAISE

The considered raise and extension of the existing flood barrier would cost an estimated $387,000 (table 8). Because the 47-year maximum practical level of protection does not meet the Corps' current minimum standards for permanent urban structural measures, Federal participation in this project cannot be recommended. Therefore, the entire cost would be the responsibility of local interests.

Table 4 - Reach 1 - Belmont Coulee closure cost sharing

Item	Costs for 100-year level of protection[1]
Present cost-sharing policy:	
Federal	$692,000
State (none)	0
Local[2]	0
Total first costs	692,000
President's proposed policy:	
Federal (75% of first costs)	519,000
State (5% of first costs)	35,000
Local (20% of first costs)	138,000
Total first costs	692,000

[1] Given level of protection of North Dakota State Water Commission's closure structure plan.

[2] Covers lands, easements, rights-of-way, and relocations.

Table 5 - Reach 1 - Belmont Coulee closure benefit-cost analysis

Item	Benefit-cost data for 100-year level of protection
Federal annual costs[1]	$47,600
Non-Federal annual costs[1]	2,400
Total annual costs	50,000
Total average annual benefits	25,000
Benefit-cost ratio	0.5
Net average annual benefits (nearest $1,000)	-25,000

[1] On the basis of present cost-sharing policy, 6 7/8-percent interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance.

Table 6 - Reach 1 - Belmont Road raise

Item	Costs for 50-year level of protection[1]
Present cost-sharing policy:	
Federal	$259,000
State (none)	0
Local[2]	25,000
Total first costs	284,000
President's proposed policy:	
Federal (75% of first costs)	213,000
State (5% of first costs)	14,000
Local (20% of first costs)	57,000
Total first costs	284,000

[1]Maximum practical level of protection (with 1 foot of freeboard). Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply if this policy were relaxed.
[2]Covers lands, easements, rights-of-way, and relocations.

Table 7 - Reach 1 - Belmont Road raise benefit-cost **analysis**

Item	Benefit-cost data for 50-year level of protection
Federal annual costs[1]	$17,800
Non-Federal annual costs[1]	2,000
Total annual costs	19,800
Total average annual benefits	10,000
Benefit-cost ratio	0.5
Net average annual benefits (nearest $1,000)	-10,000

[1] On the basis of present cost-sharing policy, 6 7/8-percent interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance. Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply if this policy were relaxed.

Table 8 - Reach 2 - Lincoln Park flood barrier raise first costs	
Item	Costs for 47-year level of protection[1]
Levee raise and extension	$77,000
Floodwall extension	155,000
House purchases[2]	100,000
Lands and rights-of-way	5,000
Total construction[2]	337,000
Engineering, design, supervision, and administration[3]	50,000
Total first costs	387,000

[1] Maximum practical level of protection due to lack of high ground to tie back into.
[2] Includes 25% for contingencies.
[3] 15% of total construction costs.

The Corps could participate in a temporary barrier raise during a flood emergency. Further information regarding flood emergency operations is provided in the Flood Emergency Plan for Grand Forks, North Dakota, published as a separate document developed in conjunction with the urban study.

Permanently raising the Lincoln Park flood barrier from a 30- to 50-year level of protection would benefit over 700 homes behind the existing barrier plus several more homes currently outside the protected area. Two homes would require relocation; 10 additional homes would require extensive landscape measures. Eight homes would remain between the floodwall extension and the river. Very minor short-term environmental impacts are anticipated because required construction areas are presently grassed lawns which would be regraded and seeded when the project is completed.

REACH 5 - FLOOD BARRIER MODIFICATIONS

Modification of the stage 2 plan by replacing the 2,260-foot floodwall with either a levee or a levee and floodwall would significantly reduce total first costs. The reanalysis of interior drainage needs results in a further reduction in total first costs. Total first costs for a 100-year level of protection using a 1,060-foot floodwall and a 1,570-foot levee in lieu of the 2,260-foot floodwall plus revised interior drainage measures would be $3,643,000 at August 1979 price levels. A 2,630-foot levee would result in total first costs of $4,467,000. Table 9 compares first costs for both the 100- and 50-year levels of protection with and without the considered flood barrier modifications.

Federal and non-Federal first costs with the 100-year levee-floodwall combination would be $2,946,000 and $697,000, respectively, under the present cost-sharing policy. Substitution of the 2,630-foot levee would reduce Federal first costs to $2,427,000 and increase non-Federal first costs to $2,040,000. A comparison of Federal and non-Federal first costs for alternative Reach 5 improvements with the President's proposed cost-sharing policy is also given in table 9.

Average annual charges for these alternatives would be $269,800 and $327,500, respectively, at a 6 7/8-percent interest rate and 100-year economic life. Corresponding average annual benefits, including benefits attributable to the reduction of future flood damage growth to residential contents, are estimated at $88,000, yielding an unfavorable benefit-cost ratio of 0.3 for a 100-year level of protection (table 10).

The levee-floodwall alternative would have fewer negative social impacts than the stage 2 plan because only six houses would be relocated instead of nine. Conversely, 22 homes would have to be relocated if a levee alone was used instead of the levee-floodwall. Permanent closure of Lewis Boulevard immediately north of U.S. Highway 2 would have long-term adverse impacts. An alternative closure with removable stop logs would reduce this impact, but at increased first costs of about $90,000.

Table 9 - Reach 5 - Flood barrier modifications cost sharing

Item	Costs for different levels of protection					
	Update stage 2 plan costs		Plan A[1]		Plan B[2]	
	50-yr[3]	100-yr	50-yr[3]	100-yr	50-yr[3]	100-yr
Present cost-sharing policy:						
Federal	$3,928,000	$5,033,000	$1,914,000	$2,946,000	$1,573,000	$2,427,000
State (none)	0	0	0	0	0	0
Local[4]	1,057,000	1,076,000	618,000	697,000	2,024,000	2,040,000
Total first costs	4,985,000	6,109,000	2,595,000	3,643,000	3,597,000	4,467,000
President's proposed policy:						
Federal (75% of first costs)	-	-	1,946,000	2,732,000	2,698,000	3,350,000
State (5% of first costs)	-	-	130,000	182,000	180,000	223,000
Local (20% of first costs)	-	-	519,000	729,000	719,000	894,000
Total first costs	-	-	2,595,000	3,643,000	3,594,000	4,467,000

1 Stage 2 plan revised by substituting a levee/floodwall in lieu of 2,260-foot floodwall.

2 Stage 2 plan revised by substituting a 2,630-foot levee in lieu of 2,260-foot floodwall.

3 Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply if this policy were relaxed.

4 Lands, easements, rights-of-way, relocations.

Table 10 - Reach 5 - Flood barrier modifications benefit-cost analysis

Item	Benefit-cost data for different levels of protection					
	Updated stage 2 plan data		Plan A[1]		Plan B[1]	
	50-yr[1]	100-yr	50-yr	100-yr	50-yr	100-yr
Federal annual costs[2]	$270,400	$346,500	$131,800	$202,800	$108,300	$167,100
Non-Federal annual costs[2]	86,300	91,900	61,100	67,000	153,[illegible]	16[illegible]
Total annual costs	356,700	438,400	192,900	269,800	262,100	327,500
Total average annual benefits	59,000	90,000	59,000	88,000	59,000	88,000
Benefit-cost ratio	0.2	0.2	0.3	0.3	0.2	0.3
Net average annual benefits (nearest $1,000)	-298,000	-348,000	-134,000	-182,000	-203,000	-238,000

1 Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply if this policy were relaxed.

2 On the basis of the present cost-sharing policy, 6 7/8-percent interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance.

The modifications to the stage 2 plan would have relatively minor additional environmental impacts. The plan A and plan B alternatives would require a slightly wider base area with a corresponding loss of a few large shade trees behind the residences.

REACH 6 - ENGLISH COULEE CLOSURE

Floodwater routing studies indicate that, with the dam and upstream diversion structure in place and without coincidental high stages on the Red River of the North, the closure structure's culverts would have sufficient flow capacity to pass a 100-year flood flow from both the 28.6- and 36.8-square-mile drainage areas without exceeding the maximum allowable ponding elevation. Estimated total Federal and non-Federal first costs for the closure structure and 506,000-gpm pumping station with the current Federal cost-sharing policy would be $1,332,000 and $19,000, respectively, for a 100-year level of protection (table 11). Total annual costs, including allowances for operation, maintenance, and scheduled replacement of major equipment items are estimated at $93,900 (table 12).

At the 100-year level of protection, the considered closure and pumping measures would reduce total average annual flood damages about 54 percent, yielding average annual benefits (including an allowance for reduction of future damage growth to residential contents) of about $86,000 and a benefit-cost ratio of 0.92. The current Soil Conservation Service studies have not yet advanced to a stage where flood damage reduction benefits specific to the dam and diversion can be determined. However, benefits attributable to reduced discharges along English Coulee are roughly estimated at $96,000.

The considered closure would have only minor environmental impacts because the area is recently reworked land, devoid of any trees or shrubs. Periodic increases in coulee stages between the structure and Sixth Avenue North will be of lower maximum elevation and of lesser duration than under existing conditions. The considered measures would have immediate and long-term social well-being benefits as a result of the marked reduction in recurring flood damages. No adverse social impacts are anticipated.

Table 11 - Reach 6 - English Coulee closure cost sharing

Item	Costs for different levels of protection: 4% (25-yr)[1]	2% (50-yr)[1]	1% (100-yr)[1]
Present cost-sharing policy:			
Federal	$1,060,000	$1,168,000	$1,332,000
State (none)[2]	0	0	0
Local	8,000	19,000	19,000
Total first costs	1,068,000	1,187,000	1,351,000
President's proposed policy:			
Federal (75% of first costs)	801,000	890,000	1,013,000
State (5% of first costs)	53,000	59,000	68,000
Local (20% of first costs)	214,000	238,000	270,000
Total first costs	1,068,000	1,187,000	1,351,000

1 Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply if this policy were relaxed.

2 Covers lands, easements, rights-of-way, and relocations.

Table 12 - Reach 6 - English Coulee closure benefit-cost analysis

Item	Benefit-cost data for different levels of protection: 4% (25-yr)[1]	2% (50-yr)[1]	1% (100-yr)[1]
Federal annual costs[2]	$73,000	$80,400	$91,700
Non-Federal annual costs[2]	1,500	2,200	2,200
Total annual costs	74,500	82,600	93,900
Total average annual benefits	26,000	49,000	86,000
Benefit-cost ratio	0.3	0.6	0.9
Net average annual benefits (nearest $1,000)	-49,000	-34,000	-8,000

1 Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply should this policy be relaxed.

2 Based on present cost-sharing policy, 6 7/8-percent annual interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance.

REACH 6 - COMBINED FLOOD PROOFING AND EVACUATION

Total construction costs for the considered Reach 6 measures are given by principal plan element in table 13. The considered 100-year flood proofing and evacuation measures would protect 132 structures. Under the present cost-charing policy, total Federal and non-Federal first costs would be $938,000 and $235,000, respectively (table 14). Corresponding average annual costs including an allowance for annual operation and maintenance and the amortized cost of periodic major equipment replacements would be $81,800 (table 15).

The considered 100-year measures would reduce average annual flood damages attributable to both Red River backup and upstream coulee flooding from about $223,000 (see attachment A) to about $98,000, yielding average annual benefits of about $125,000, including allowances for reduced future damages to residential contents, and a favorable benefit-cost ratio of 1.5.

Table 15 shows the benefit-cost ratio increases to about 5.6 as the design protection decreases to the 25-year level; however, only 15 structures would be protected. Furthermore, the optimum economic design (the point of maximum net benefits) occurs near the 50-year level and would involve about 45 structures.

Table 13 - Reach 6 - Flood proofing and evacuation first costs

Item	Costs for different levels of protection		
	4% (25-yr)	2% (50-yr)	1% (100-yr)
Localized flood barriers[1]	$ 91,000	$281,000	$710,000
Structure relocations	0	22,000	22,000
Structure raises	0	11,000	32,000
Utility relocations	1,000	2,000	2,000
Flood proofing, commercial bldgs.	0	23,000	45,000
Flood proofing, residences	6,000	34,000	169,000
Flood proofing, public bldgs.	0	2,000	5,000
Lands and rights-of-way	4,000	28,000	35,000
Total construction[2]	102,000	403,000	1,020,000
Engineering, design, supervision, and administration	15,000	60,000	153,000
Total first costs	117,000	463,000	1,173,000

1 Includes individual barriers around basement walkouts.
2 Includes 25% for contingencies.
3 15% of total construction costs.

Table 14 - Reach 6 - Flood proofing and evacuation cost sharing

Item	Costs for different levels of protection		
	4% (25-yr)	2% (50-yr)	1% (100-yr)
Present cost-sharing policy:			
Federal (80% of first costs)	$94,000	$370,000	$938,000
State (None)	0	0	0
Local (20% of first costs)	23,000	93,000	235,000
Total first costs	117,000	463,000	1,173,000
President's proposed policy:			
Federal (75% of first costs)	88,000	347,000	880,000
State (5% of first costs)	6,000	23,000	58,000
Local (20% of first costs)	23,000	93,000	235,000
Total first costs	117,000	463,000	1,173,000

Table 15 - Reach 6 - Flood proofing and evacuation benefit-cost analyses

Item	Benefit-cost data for different levels of protection		
	4% (25-yr)	2% (50-yr)	1% (100-yr)
Federal annual costs[1]	$6,500	$25,500	$64,600
Non-Federal annual costs[1]	1,900	7,200	17,200
Total annual costs	8,400	32,700	81,800
Total average annual benefits	47,000	83,000	125,000
Benefit-cost ratio	5.6	2.5	1.5
Net average annual benefits (nearest ($1,000)	39,000	50,000	43,000

1 On the basis of the present cost-sharing policy, 6 7/8-percent annual interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance.

The considered measures are expected to result in only minor long-term adverse environmental impacts from the localized measures in previously disturbed areas. All of the considered measures would be located on areas that have been paved or reworked and are generally devoid of original vegetation. Significant long-term social well-being benefits would result from reduced flood damages. The 100-year plan would require the relocation of two commercial structures to nearby flood-free areas. No residential structures would be relocated.

GRAND MARAIS COULEE DIVERSION

Under present conditions, the existing Grand Marais Coulee channel has essentially no excess capacity to pass Red Lake River overflows.

Passage of such overflows would only aggravate recurring flood problems at farmsteads along the coulee. However, modifications such as channel cutoffs and channel widening would increase the channel capacity to accommodate a portion of Red Lake River overflows. These overflows would provide a reduction in peak flood stages in the Grand Forks and East Grand Forks area, but only at substantial economic and environmental cost.

The considered 100-year channel diversion plan would result in total first and annual costs of $36,314,000 and $2,503,000, respectively (tables 16, 17, and 18). Corresponding average annual benefits in Grand Forks and East Grand Forks resulting from the 1.3-foot decrease in the 100-year flood stage at the Grand Forks gage would be approximately $421,000. A comparison of these 100-year benefits with related average annual costs of $2,503,000 yields an unfavorable benefit-cost ratio of 0.2.

The considered channel modifications would have obvious and severe immediate and long-term adverse impacts associated with the destruction of essentially all small mammal and waterfowl habitat along the coulee. Channelization of the coulee along with regular maintenance would permanently remove this natural riverine setting and aesthetically diverse feature. However, the modifications would produce immediate and long-term beneficial social well-being effects as a result of reduced peak flood stages in the urbanized area.

Table 16 - Grand Marais Coulee diversion first costs

Item	Costs for different levels of protection 2% (50-yr)	1% (100-yr)
Channel excavation	$15,980,000	$20,455,000
Bridge modifications	8,885,000	10,932,000
Diversion structure	125,000	125,000
Lands and rights-of-way	52,000	66,000
Total construction[1]	25,042,000	31,578,000
Engineering, design, supervision and administration[2]	3,756,000	4,736,000
Total first costs	28,798,000	36,314,000

1 Includes 25% for contingencies.
2 15% of total construction cost.

Table 17 - Grand Marais Coulee diversion cost sharing

Item	Costs for different levels of protection 2% (50-yr)[1]	1% (100-yr)
Present cost-sharing policy:		
Federal	$18,521,000	$24,213,000
State (none)	0	0
Local[2]	10,277,000	12,101,000
Total first costs	28,798,000	36,314,000
President's proposed policy:		
Federal (75% of first costs)	21,598,000	27,235,000
State (5% of first costs)	1,440,000	1,816,000
Local (20% of first costs)	5,760,000	7,263,000
Total first costs	28,798,000	36,314,000

1 Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply should this policy be relaxed.
2 Covers lands, easements, rights-of-way, and relocations.

Table 18 - Grand Marais Coulee diversion benefit-cost analysis

Item	Benefit-cost data for different levels of protection[1] 2% (50 yr)	1% (100-yr)
Federal annual costs[2]	$1,275,000	$1,667,000
Non-Federal annual costs[2]	714,000	836,000
Total annual costs	1,989,000	2,503,000
Total average annual benefits	344,000	421,000
Benefit-cost ratio	0.2	0.2
Net average annual benefits (nearest $1,000)	- 1,645,000	- 2,082,000

[1] Current policy precludes Corps participation in a permanent urban structural flood control project with this degree of protection. The table presents the cost-sharing arrangement that would apply should this policy be relaxed.

[2] Based on present cost-sharing policy, 6 7/8-percent interest rate, and a 100-year economic life. Non-Federal costs include allowance for annual operation and maintenance.

EVALUATION OF ALTERNATIVES

Each alternative was evaluated on the basis of satisfying the formulation and evaluation criteria given earlier. Principal plan impacts and trade-offs of beneficial and adverse impacts relating to these criteria were analyzed as discussed in the following paragraphs.

REACH 1 - COMBINED FLOOD PROOFING AND EVACUATION

A comparison of average annual costs and benefits indicates that the considered measures cannot be economically justified at the 100-year level of protection. However, economic feasibility appears achievable near and below the 50-year level of protection. The principal negative factor affecting economic justification for the 100-year level of protection is the high cost of flood barriers required to protect walkout levels along Terrace Drive and the Olson-Elmwood Drive areas along the Red River. Limited space between the homes and coulee or river precludes the use of less costly levees. The only possible but more costly and socially unacceptable alternative for these areas would be the removal of affected residences with the evacuated areas reverting to public greenbelt areas.

The flood proofing and evacuation measures would generally satisfy the established technical criteria with one exception. Because sufficiently high ground elevations are not available, it would be clearly impractical to provide a 3-foot freeboard allowance for the considered tieback levees that would extend landward from the barrier around the Grand Forks recreational building. Similarly, and in lieu of a ring levee around the building, it would be impractical to incorporate a standard project flood level of protection within the limited flood barrier height.

The considered measures would also satisfy the environmental criteria in minimizing adverse ecosystem effects. Social well-being criteria would be generally satisfied with a long-term reduction in area flood damages and other flood-related problems. For the entire reach, the considered measures would result in only minor localized adverse environmental effects (principally vegetative losses) because the affected areas are lawns or pavement. Social well-being impacts would be generally beneficial with minor adverse impacts resulting from altered local landscapes associated with flood proofing barriers in and around affected structures.

REACH 1 - BELMONT COULEE CLOSURE

The considered closure measures are desired by the city and affected residents but are economically unustified as indicated by the 0.5 benefit-

cost ratio. Substitution of temporary pumping measures for the permanent works would result in a favorable benefit-cost ratio; however, this modification woul' not be in concert with established Corps design criteria. The considered trade-offs of some landscape changes in the immediate project area to obtain an appreciable measure of protection would be acceptable to local interests.

REACH 1 - BELMONT ROAD RAISE

The considered road raise is technically feasible but not economically justified as indicated by the 0.5 benefit-cost ratio. Relocation of the existing sanitary lift station which periodically requires flood proofing would be in concert with the city's long-range sewer system improvement program. Some of the required driveway grade raises near 15th Avenue South would be unavoidably steep, but still usable. Containing the raised roadway section to the east side of the street would minimize adverse effects on established residential landscapes. Encroachment of the widened road fill into Lincoln Park property would have no significant adverse effect.

REACH 2 - LINCOLN PARK FLOOD BARRIER RAISE

Detailed field topographic surveys have established that it is clearly impractical to obtain a 100-year level of protection with 3 feet of freeboard. The maximum obtainable increase in the existing 30-year level of protection would be to a 47-year level with 3 feet of freeboard. This level of protection does not meet minimum acceptable Corps standards for urban structural measures and, therefore, precludes Corps participation in funding such construction. The 47-year level of protection would require raising the existing barriers nearly 2 feet, and analyses would have to be conducted to identify possible soil stability problems. A large raise could possibly result in foundation settlement and possible failure of the downstream levee extension (see Attachment B). A comparison of average annual costs with related benefits indicates that the considered barrier raise and extension is clearly not economically justifiable.

The raise to a 47-year level of protection would generally satisfy the established environmental criteria of minimizing adverse ecosystem effects. Attainable beneficial social well-being effects would be minor. Short-term adverse effects resulting from the temporary disruption of established residential areas would be unavoidable as would the exclusion of eight residences from the protected area. The floodwall extension could physically be placed riverward of the homes but only at substantial increases in costs to already unjustified measures.

REACH 5 - FLOOD BARRIER MODIFICATIONS

A comparison of annual costs and benefits indicates that the considered flood barrier adjustments would improve the benefit-cost ratio over that obtained for the flood barrier system considered in stage 2. However, economic viability is still clearly lacking for this reach. Any further adjustments in barrier alignment or type would not improve on this situation. The Reach 5 measures generally satisfy technical criteria except in terms of sufficient freeboard and questionable slope stability. The maximum practical level of freeboard based on tiebacks to existing high ground would be about 2.5 feet at the 100-year flood level. Since much of the considered alignment would be within a zone with potential foundation problems, the stability of the considered levee particularly between U.S. Highway 2 and Riverside Drive is questionable pending detailed foundations analysis (see Attachment B).

The flood barrier alterations would generally meet the environmental criteria with the exception of greater shade tree losses with a levee in lieu of the 2,260-foot floodwall considered in stage 2.

Overall social well-being effects would be beneficial with the reduction of potentially severe damages to over 380 homes. The loss of 22 established residences would be a major short-term adverse social impact.

REACH 6 - ENGLISH COULEE CLOSURE STRUCTURE

The 0.92 benefit-cost ratio at the 100-year level of protection indicates a lack of economic feasibility on the basis of available data and analyses to date. This alternative satisfies all appropriate technical criteria except that the maximum practical freeboard with the 100-year plan would be 2.5 feet instead of the desired 3 feet because of insufficiently high ground in the project area. It would be impractical to incorporate the standard project flood level within the freeboard range.

The derivation of average annual benefits for this alternative was accomplished using preliminary estimates of peak discharges from the coulee drainage area. Concurrent studies of the coulee's hydrologic and hydraulic characteristics by the Soil Conservation Service and Federal Emergency Management Agency were considered during analysis of this alternative. In addition, the St. Paul District's consultant independently developed frequency-discharge relationships for the study area. However, further in-house studies are considered advisable to reconcile differences between the results from these sources.

Base flood damage data used were October 1977 data updated by price level indexes to August 1979 price levels. In addition, the District's consultant conducted damage surveys after the 1979 flood to extend coverage to areas not included in the original surveys and update for new developments

The estimated first and annual costs of this alternative are strongly influenced by the size and cost of the required interior runoff pumping measures. Thus, any reduction in pumping costs resulting from Soil Conservation Service measures in the upper part of the coulee's watershed will have positive economic impacts and may reverse the present marginally infeasible economic analysis.

The considered measures generally satisfy the environmental criteria in minimizing adverse ecosystem effects. They also satisfy social well-

being criteria in terms of reducing the possibility of loss of life and threats to public health and safety. The concept of a ponding area along a designated coulee reach may be perceived as an adverse effect by nearby residents, but in reality the ponding area would not change any established community systems.

REACH 6 - COMBINED FLOOD PROOFING AND EVACUATION

A comparison of average annual costs and benefits indicates that 100-year measures would be economically justified. However, several factors influence and a reevaluation of project benefits could significantly affect this favorable finding.

The plan provides for temporary interior drainage measures (such as portable pumps) in leveed areas containing individual structures or clusters of buildings. Permanent interior drainage collection and pumping facilities conforming to current Corps design criteria would significantly increase project first costs and reduce the benefit-cost ratio. The second factor influencing the economic justification is the use of very preliminary hydrologic and hydraulic data in determining discharge-damage and frequency-damage relationships. A refinement of the hydrologic and hydraulic data may result in significant changes in average annual flood damages and related benefits.

The effectiveness of this overall plan depends very much on the provision of effective temporary closure measures between DeMers Avenue and the Burlington Northern railroad embankment at the junction with South 30th Street during a major flood occurrence. It also depends on the assumed practicability of temporary pumping (using portable pumps) of interior run-off from the floodplain areas located east of and protected by the South 30th Street road raise. A permanent closure measure and permanent interior drainage pumping facilities would further impair the benefit-cost ratio.

The considered measures would result in only minor localized adverse environmental effects because the work affects either lawns or paved areas. Vegetation losses would be minimal; the established environmental planning objective would be satisfied. Social well-being impacts would generally be beneficial as a result of reduced economic flood losses and reduced threats to public health and safety. The presence of concrete and/or earthen flood barriers adjacent to or around structures would affect individual property landscapes and impair views of the coulee in some cases. Access to buildings raised on fill would be permanently altered.

GRAND MARAIS COULEE DIVERSION

The capacity of the existing Grand Marais Coulee channel is presently taxed by runoff from the coulee drainage area and natural overflows from the Red Lake River. Any increases in overflows would exceed the existing channel capacity and result in inundation and damages to 28 farmsteads and adjacent cropland. Widening of the channel and numerous cutoffs and bridge modifications would provide for additional overflows but at considerable economic and environmental costs.

The exact amount of overflows at the peak 100-year Red Lake River discharge cannot be determined without more detailed hydrologic studies (rating curve relationships at the point of breakout); however, computerized backwater studies along the coulee make it reasonably certain that neither the natural nor modified channel could handle the overflows without major channel widening and bridge raising and lengthening measures.

A comparison of annual costs and benefits for channel modifications along the coulee indicates that such measures would be grossly economically infeasible. Benefits are limited because of the small percentage of diverted Red Lake River flows compared with total Red River peak flood flows. The measures would clearly violate the established environmental planning objectives because of serious permanent losses of riverine woodlands, wetlands, and associated wildife habitat along the coulee. The measures

would, to a degree, satisfy the social well-being objectives in terms of a reduction in flood damages in the urbanized area. However, given the excessive local financial burden for required lands and bridge modifications, it is very unlikely that area residents would find the channel modification measures acceptable.

EFFECTS OF REVISING THE FREQUENCY-DISCHARGE RELATIONSHIP OF THE RED RIVER OF THE NORTH

Subsequent to the start of this study, the St. Paul District has concluded, on the basis of higher estimates of peak discharges of recorded and historic (pregage) floods in the 19th century and the recent history of frequent major flooding, that the frequency-discharge relationship for the Red River at Grand Forks should be revised. The effect on the 100-year flood is an increase in peak discharge from 89,000 cfs[1] to about 106,000 cfs and a corresponding stage increase from 50.6 feet at the Grand Forks gage to about 52.4 feet. The 89,000-cfs discharge now corresponds to about a 55-year flood or 1.8-percent event.

The St. Paul District has determined that these revised data will be applied to all future Corps flood control studies in the Grand Forks-East Grand Forks area. However, the basis of existing local floodplain management programs will continue to be the administratively agreed upon 89,000-cfs 100-year discharge.

The revised frequency-discharge relationship redefines the 100-year flood so that damages from such an event in Grand Forks would be 72 percent greater than with the old relationship. The revised 100-year flood would inundate much of the city's urbanized area. The 1.8-foot increase in stage would increase total area 100-year flood damages from $53 million (August 1979 price levels) to about $89 million. Because sufficiently high ground is already unavailable in most areas of Grand Forks for flood barrier tie-backs capable of providing 3 feet of freeboard, the only technically feasible solution would be a ring barrier around the entire community together with necessary closure structures and interior drainage measures, an alternative found to be grossly infeasible in stage 2.

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[1] As administratively agreed to by the Corps of Engineers; U.S. Geological Survey, North Dakota and Minnesota Districts; Soil Conservation Service; U.S. Department of Agriculture; North Dakota State Water Commission; and Minnesota Department of Natural Resources on 15 June 1971

During stage 3, sensitivity analyses were conducted to examine the impact of the revised frequency-discharge relationship on the urban study's conclusions. Specifically, the Corps wanted to determine if any of the alternatives that lacked feasibility with the old relationship might become feasible with the new relationship. Detailed analyses were not conducted on the English Coulee closure alternative nor on the combined flood proofing and evacuation alternatives for Reaches 1 and 6 because these alternatives already warranted further, more detailed consideration (see the recommendations section of this report). Despite the new frequency-discharge relationship, none of the previously rejected alternatives could meet the economic and technical criteria needed to warrant Corps participation in their implementation.

RECOMMENDATIONS

The following recommendations are directed at two audiences: local interests - regarding what they might do with a reasonable investment to significantly reduce their flood susceptibility - and Corps higher authority - regarding what direction future studies might take to determine the eventual Federal role in permanent flood damage reduction measures.

NONSTRUCTURAL IMPROVEMENTS BY LOCAL INTERESTS

- The city should enforce existing floodplain management ordinances to preclude further residential, business, or other development in the 100-year floodplain unless such development is in accordance with said ordinances.

- The city should annually notify local floodplain residents of the extent and level that these properties would be affected by the 100-year flood.

- The city should maintain its eligibility in the Federal flood insurance program. The city should encourage property owners to participate in the program by annually reminding them of the availability, benefits, and requirements.

- Public agencies, individual property owners, and businesses should undertake, where feasible, modifications to flood proof their properties. The Corps of Engineers can, through its Technical Services Program, assist the city and property owners in the selection and design of appropriate measures. Initial emphasis should be on English Coulee flood-prone developments where such measures are economically feasible.

- The city should consider purchasing and removing, as they become available, those floodplain properties located more than 100 feet within the 100-year floodplain or having a first-floor elevation below the 100-year flood level. The ultimate goal would be to develop the evacuated areas as recreational or open-space areas. The city should evaluate the feasibility of using U.S. Department of Housing and Urban Development Block Grant funds for this purpose.

- The city should annually review and update the flood emergency plan of action flood fight manual developed during the urban study through a joint city, Corps, and consultant effort.

STRUCTURAL IMPROVEMENTS BY LOCAL INTERESTS

Grand Forks should consider the following structural measures. These measures, though not economically justifiable when the Corps' extremely high design standards are used, might be built by the city at a significant cost savings with some modifications to the Corps' design. For example, interior drainage can be handled much cheaper by temporary, portable pumps than by a permanent pumping station.

- Although Federal participation is not economically justifiable, the city should consider constructing a closure structure and providing interior drainage pumping facilities at the Belmont Road crossing of Belmont Coulee to prevent flooding from Red River backwater.

- Although Federal participation is not economically justifiable, the city should consider raising Belmont Road between 13th and 17th Avenues South, relocating the sanitary sewage lift station in the area, and providing temporary pumping measures for interior drainage during floods.

- For the long term, the city should consider relocating the Lincoln Park recreation building to adjacent high ground.

- Although Federal participation is not economically justified, the city should consider raising Stanford Road near U.S. Highway 2 and providing an operable closure on the culvert through Stanford Road to prevent flooding of structures adjoining a swale tributary to English Coulee.

FURTHER STUDIES

- The following alternatives should be studied in greater detail:

  - Reach 1 - Combined flood proofing and evacuation.
  - Reach 6 - English Coulee closure.
  - Reach 6 - Combined flood proofing and evacuation.

Table 19 summarizes the results of the economic analyses for these alternatives. Flood proofing and evacuation in Reach 1 is economically justifiable below the 50-year level of protection. The closure structure/pumping station is marginally infeasible (benefit-cost

ratio 0.92 at the 100-year level of protection), but resolution of uncertainties in the hydrology, hydraulics, and flood damage analyses could reverse the feasibility picture. Flood proofing and evacuation in Reach 6 is economically feasible up to and beyond the 100-year level of protection.

Table 19 - Summary of economic data - alternatives recommended for further study[1]

Item	Level of protection (percent)	Reach 1 - Combined flood proofing	Reach 6 - English Coulee closure	Reach 6 - Combined flood proofing and evacuation
First costs				
	4	$20,000	$1,068,000	$117,000
	2	431,000	1,187,000	463,000
	1	2,596,000	1,351,000	1,173,000
Average annual costs				
	4	1,700	74,500	8,400
	2	31,800	82,600	32,700
	1	182,900	93,900	81,800
Average annual benefits				
	4	12,000	26,000	47,000
	2	31,000	49,000	83,000
	1	58,000	86,000	125,000
Net annual benefits (nearest $1,000)				
	4	10,000	-49,000	39,000
	2	- 1,000	-34,000	50,000
	1	-125,000	- 8,000	43,000
Benefit-cost ratio				
	4	7.1	0.4	5.6
	2	0.97	0.6	2.5
	1	0.3	0.92	1.5
Structures involved				
	4	19	NA	15
	2	74	NA	45
	1	200	NA	132

[1] August 1979 price levels, 100-year economic life, 6 7/8-percent interest rate.

- The Corps should also evaluate the feasibility of increasing the capacity of the culvert just downstream of DeMers Avenue which carries English Coulee under the Burlington Northern railroad tracks. In 1979, ponding of coulee runoff behind this culvert caused serious flooding to neighboring properties. Studies are needed to determine if the culvert can be enlarged sufficiently to prevent upstream flooding without causing additional downstream flooding.

- The recommended studies should be transferred to the small flood control project continuing authority (Section 205 of the 1948 Flood Control Act, as amended). The Section 205 continuing authority offers a more expeditious means to accomplish more detailed studies and potential construction. Furthermore, because of the work already accomplished during the urban study, the time to complete a project under the Section 205 authority would be reduced considerably. Conversely, continuation via the normal feasibility study route could typically involve a time line ranging from 8 to 14 years for Washington-level review, preconstruction planning, and congressional authorization and funding. During this period, the rising Federal discount rate would continue to erode the economic feasibility of promising measures and would certainly destroy the opportunity for Federal participation in any measure already marginal.

- During the Section 205 studies of English Coulee alternatives, the Corps should maintain close coordination with the Soil Conservation Service.

In March 1981, the Soil Conservation Service published a preauthorization report on its preliminary findings regarding flood control measures in the English Coulee watershed. These findings show apparent economic feasibility for an alternative consisting of the dry dam in conjunction with a diversion ditch west and north of the city. These results are preliminary and will need additional substantiation.

The Soil Conservation Service results will dramatically affect the feasibility of the English Coulee alternatives the Corps is considering. The Service's measures might reduce flows entering the city (and thereby reduce damages in the urban area) to the extent that none of the Corps' measures are justifiable or needed. However, without a flow reduction, the pumping requirements of the closure alternative are impracticable. Consideration must be given to the two agencies' alternatives independently and jointly to develop the optimum overall plan for resolving the coulee's flood problems.

- Specific topics that need further attention during the Section 205 studies include:

  - *Topographic mapping*. Because of the flatness of the study area, a small change in flood elevation can result in a substantial change in the number of damaged properties. Better topography will improve both the hydraulic and economic analyses and could significantly affect feasibility findings.

  - *Flood damage and benefit analyses*. Before the 1979 flood, backwater from the Red River was the only recognized flood threat along the English Coulee. The most comprehensive damage survey and analysis in the area flooded in 1979 by coulee runoff was conducted in late 1979 and early 1980 by a consulting engineering firm in conjunction with the urban study. The consultant's findings should be reviewed in light of new topographic, hydraulic, and hydrologic data and updated residential depth/damage tables. The results of this review will also affect the Soil Conservation Services' plans because about 46 percent of the benefits from the most cost-effective alternative are derived from protection afforded the urban area. These urban benefits are based on economic data provided by the Corps.

  - *Hydraulics and hydrology*. The revised Red River frequency-discharge relationship will be the basis for the designs and economic analyses used in the Section 205 studies. Preliminary sensitivity checks showed that the effect of the "new" frequency-discharge

relationship on the benefit-cost ratio cannot be predicted - the relative rates of increase in costs and benefits must be considered on a case-by-case basis.

The English Coulee's hydraulics and hydrology are not well defined. There are no historic gage records, and high-water marks from major flood flows down the coulee are limited to those collected in 1979. There are at least four sources of hydraulic and/or hydrologic analyses of the coulee - the Soil Conservation Service, the Federal Emergency Management Agency, and two consulting firms that worked on the urban study.

The Soil Conservation Service hydrology focuses on hypothetical rainfall runoff events, probably because summer floods present the greatest threat to rural interests in the upper watershed. However, the St. Paul District feels consideration must be given to spring floods, too, to accurately assess the urban area's most serious flood threat.

The Federal Emergency Management Agency will be issuing a revised Grand Forks flood insurance study on 31 July 1981. The February 1977 flood insurance study did not recognize the threat from coulee runoff. The St. Paul District reviewed the draft hydraulic and hydrologic work conducted by the Agency's consultants and determined that there were still concerns warranting further study.

One of the consultants working on the urban study developed separate coulee frequency-discharge relationships for spring and summer runoff events. The other consultant reviewed coulee hydraulics and hydrology with regard to their impacts on the Grand Forks urban drainage master plan. The results of these consultants differed enough from those of the Soil Conservation Service and Federal Emergency Management Agency to warrant further studies to reconcile the discrepancies.

- Environmental/social impact analyses. An Environmental Impact Statement or Finding of No Significant Impact will be needed if one of the considered alternatives is recommended for construction as a result of the Section 205 studies. The greatest potential for biological impacts is presented by the Soil Conservation Service dry dam and diversion channel measures for the English Coulee. These impacts must be addressed by the Service in its continuing studies. Of the Corps alternatives recommended for further study, the closure structure has the most likelihood of significant biological impacts.

  Social impacts will be greatest with the flood proofing and evacuation alternatives. During the urban study, a survey was conducted to determine the public's perception of floods and flood control measures and the impacts of flood protection or lack of protection. The responses to this survey will be analyzed as part of the Section 205 effort.

  As part of the urban study, a cultural resources literature search and records review was conducted for both Grand Forks and East Grand Forks. Although numerous significant sites were identified, additional studies, particularly standing structure surveys, would probably locate other significant sites.

  Impacts on existing recreational facilities and modifications to improve recreational opportunities should be consid ed when formulating the recommended alternatives.

ATTACHMENT A

DERIVATION OF BENEFITS

ATTACHMENT A
DERIVATION OF BENEFITS

GENERAL

This attachment provides a brief discussion on the methodology used in computing average annual benefits for the alternative plans considered. Specifically discussed are historic flood damages, present condition damages, effects of the affluence factor on future damage growth to residential contents, and total average annual benefits. Also discussed are the empirical methods used to adjust benefit estimates for certain alternative plans.

EVALUATION OF FLOOD DAMAGES

CHARACTERISTICS OF FLOOD AREAS

Grand Forks is subject to periodic flooding of the Red River; flooding begins at a stage of about 28 feet (gage zero = 778.35 feet above mean sea level, 1929 adjustment). Appreciable flood damages begin along the Red River at a stage of about 35 feet in unprotected areas. Flood damages along Reach 2 commence at a stage of about 50 feet because of overtopping of the existing levee. Significant damage along English Coulee usually is caused by backwater flooding from the Red River and begins at a stage of about 46.7 with flooding of walkout level basements and some commercial structures.

Because of the flat topographic relief, a large part of the urbanized area is subject to either direct or indirect flooding. Over 2,600 residential, commercial, and public buildings would be subject to direct flooding from a 1-percent chance flood. Floof-prone structures in the floodplain for the reaches considered in stage 3 are listed below:

Reach	Number of structures Residential	Commercial	Public
1 (Belmont Road and Coulee)	256	1	2
2 (Lincoln Park)	740	0	0
5 (Riverside Park)	382	19	1
6 (English Coulee)	358	26	4

HISTORIC FLOOD DAMAGES

Recent major floods occurred in 1965, 1966, 1969, 1975, 1978, and 1979. Major disasters were averted through emergency flood fights. A summary of total flood damages incurred at Grand Forks and damages prevented by the existing Corps Reach 2 project and emergency flood fight measures is given in table A-1.

Table A-1 - Summary of historic flood damages[1]

Year	Peak flood stage (ft)	Total flood damages	Damages prevented
1965	44.92	$306,000	$578,000
1966	45.55	516,000	1,044,000
1969	45.69	420,000	897,000
1975 (Spring)	43.27	758,000	2,238,000[2]
1975 (Summer)	43.08	496,000	
1978	45.73	82,000	3,256,000
1979	49.5	7,450,000	11,909,000

[1] Taken from respective post-flood reports.

[2] Total for 1975 spring and summer floods.

PRESENT FLOOD DAMAGES

Under present conditions, extensive residential, public, and commercial-industrial development in Reaches 1, 2, 5, and 6 is subject to direct and indirect flood damages. Direct damages include surface flooding effects, while indirect damages include the adverse effects of seepage and sewer backup. Present condition total flood damages (based on August 1979 price levels) are given in table A-2.

Table A-2 - Summary of total flood damages

Reach	50-year flood level	100-year flood level	Standard project flood level
1	$1,487,000	$2,723,000	$4,519,000
2	4,073,000	6,635,000	10,982,000
5	1,899,000	2,906,000	5,148,000
6	2,288,000	5,686,000	7,322,000

Elevation-damage and frequency-damage relationships were developed for the given reaches to analyze the present condition flood damage potential (figures A-1 through A-4). Present condition average annual damages updated to August 1979 price levels are given in table A-3.

Table A-3 - Summary of present condition average annual damages (100-year flood level)

Reach	Flood damage category: Residential	Public	Comm.-Indust.	Total average annual damages
1	$78,800	$1,100	$ 0	$79,900[1]
2	153,200	3,100	0	156,300
5	98,700	5,700	2,000	106,400
6	118,500	2,300	3,000	123,800
Grand Forks	497,200	112,200	618,900	1,228,300
E. Grand Forks	346,400	25,800	617,300	989,500

1 $79,000 = $69,800 x 1.144 (see figure A-1).

FUTURE FLOOD DAMAGES

Flood damages attributable to future developmental growth would be limited to conforming floodplain uses, development above the 100-year flood level, or flood-proofed developments. For instance, the estimated number of future structures in Reach 6's 100-year floodplain is given in table A-4 for present or 1980 base year conditions and 2030 conditions. No increases in numbers of residential and commercial-industrial structures are projected for the period of analysis.

Table A-4 - Reach 6 - Estimated future development

Development category	Number of structures: Existing (1980)	Number of structures: Future (2030)
Residential	358	358
Public	11	20
Commercial-industrial	26	26

In accordance with ER 1105-2-351 only the growth in damages to residential contents is evaluated. The future maximum value of contents in the study area was estimated at 75 percent of the structure value. For instance, the existing residential property valuation in Reach 6 is about $13,604,000 for 358 structures affected by flooding. A maximum future contents value of 75 percent of the structure value compared to the estimated current contents value of 25 percent of the structure value yields a 3.0 limiting growth factor. A per capita income growth factor of 4.34 (from an analysis of area trends) indicates a 3.00-percent compound growth factor. With the limiting factor of 3.0 and a 3.00-percent growth rate, future growth of residential contents damages will cease in year 37.

With a 1980 base year, average annual residential damages in Reach 6 of $123,800, and estimating that contents account for 40 percent of flood losses, the base year average annual damage to contents in this reach would be $49,500. Adjusted unit flood damages for Reaches 1, 2, 5, and 6 are given for year 1980 in table A-5.

Table A-5 - Unit flood damages

Reach	Unit flood damages: Structure	Contents	Total
1	$184.61	$123.09	$307.70
2	124.17	82.78	206.95
5	154.97	103.32	258.29
6	198.66	132.43	331.09

Table A-6 shows the adjusted unit flood damages for selected years reflecting the affluence factor.

Table A-6 - Adjusted unit residential flood damages

Reach	Category	Year: 1980	2017[1]	2030
1	Structure	$184.61	$184.61	$184.61
	Contents	123.09	372.96	372.96
		307.70	557.57	557.57
2	Structure	124.17	124.17	124.17
	Contents	82.78	250.82	250.82
		206.95	374.99	374.99
5	Structure	154.97	154.97	154.97
	Contents	103.32	313.06	313.06
		258.29	468.03	468.03
6	Structure	198.66	198.66	198.66
	Contents	132.43	401.26	401.26
		331.09	599.92	599.92

[1] Year in which growth ceases (year 37).

Future average annual damages for the four reaches were computed by applying the unit data in table A-6 to the total number of structures (table A-7). Similar data for the Grand Forks and East Grand Forks areas are given in table A-8.

Public damages are projected to increase as shown in tables A-7 and A-8. Lacking definitive plan expansion plans for present commercial and industrial development and recognizing that future development would be constructed above the 100-year flood level, no future growth in damages was projected for such development. Total average annual flood damages for the four selected reaches are shown on figures A-1 through A-4.

FLOOD DAMAGE REDUCTION BENEFITS

GENERAL

Flood damage reduction benefits considered reflect the difference between average annual flood damages with and without the considered alternative plans. The derivation of present condition benefits (in terms of October 1977 price levels) based on the reduction of average annual damages is shown on the frequency-discharge quadrants of figures A-1 through A-4.

Present condition residential and public benefits are considered to increase in the same proportion as future flood damages in the determination of benefits resulting from the reduction in future flood damages. The derivation of average annual benefits for the selected reaches for a 100-year level of protection is shown on table A-9. Similar computations for the 50- and 25-year levels of protection are given in table A-10. Present and future condition benefits (100-year level) for the entire Grand Forks-East Grand Forks study area are given in table A-11. Similarly, table A-12 displays average annual benefits for the entire study area for the 50- and 25-year levels of protection. A summary of total average annual benefits for the individual study reaches and the entire study area is given in table A-13.

Table A-7 - President and future average annual damages, Grand Forks reaches

Flood damage category	Average annual damages existing conditions	Projected future average annual future flood damages including effect of affluence factor 2017	2030	Future growth (1980-2030)	Average annual equivalent of future growth	Total average annual flood damages
Reach 1						
Residential	$78,770	$142,740	$142,740	63,970	21,980 [1]	$100,740
Public	1,080	1,860	2,160	1,080	320	1,400
Comm. & indust.	0	0	0	0	0	0
Total	79,850	144,600	144,900	65,050	22,300	102,140
Reach 2						
Residential	153,150	277,490	277,490	124,340	42,720	195,870
Public	3,120	5,360	6,240	3,120	930	4,050
Comm. & indust.	0	0	0	0	0	0
Total	156,270	282,850	283,730	127,460	43,650	199,920
Reach 5						
Residential	98,670	178,790	178,790	80,120	27,530	126,200
Public	5,720	9,840	11,440	5,720	1,710	7,430
Comm. & indust.	2,000	2,000	2,000	0	0	2,000
Total	106,390	190,630	192,230	85,840	29,240	135,630
Reach 6						
Residential	118,530	214,770	214,770	96,240	33,070	151,600
Public	2,250	3,870	4,500	2,250	670	2,920
Comm. & indust.	3,000	3,000	3,000	0	0	3,000
Total	123,780	221,640	222,270	98,490	33,740	157,520

[1] Average annual equivalent factor = 0.3436 for 37 years of growth and no growth thereafter during the 100-year economic life.

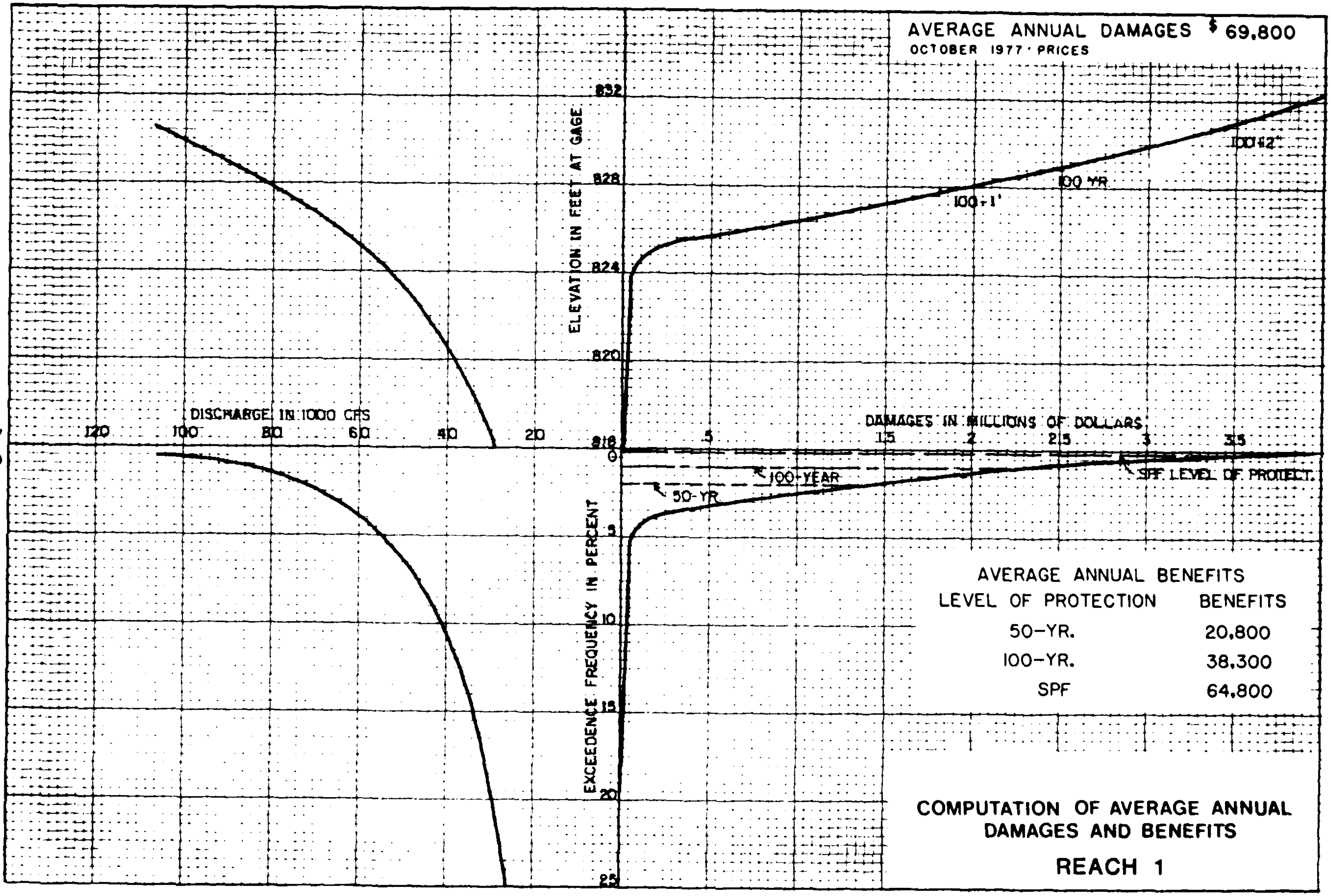
Table A-8 - Projected future flood damages including effects of affluence factor, Grand Forks-East Grand Forks

Flood losses by category	Average annual damages, existing conditions (1980)	2000	2017	2030	Increase (1980-2030)	Average annual equivalent of increase	Total average annual damages
Grand Forks							
Residential	$ 434,830	$ 567,500	$ 786,100	$ 786,100	$351,300	$120,700[2]	$555,500
Public	74,600	104,400	128,300	149,100	74,600	22,300[3]	96,900
Comm. - indust.	718,900	718,900	718,900	718,900	0	0	718,900
Total average annual damages	$1,228,300	$1,390,800	$1,633,300	$1,654,100	$425,900	$143,000	$1,371,300
East Grand Forks							
Residential	$ 346,400	$ 452,100	$ 626,200	$ 626,200	$279,800	$ 96,100	$442,500
Public	25,800	36,200	44,500	51,600	25,000	7,700	33,500
Comm. - indust.	617,300	617,300	617,300	617,300	0	0	617,300
Total average annual damages	$ 989,500	$1,105,600	$1,288,000	$1,295,100	$305,600	$103,800	$1,093,300
Total Grand Forks and East Grand Forks	$2,217,800	$2,496,400	$2,921,300	$2,949,200	$731,500	$246,800	$2,464,600

1 August 1979 prices.

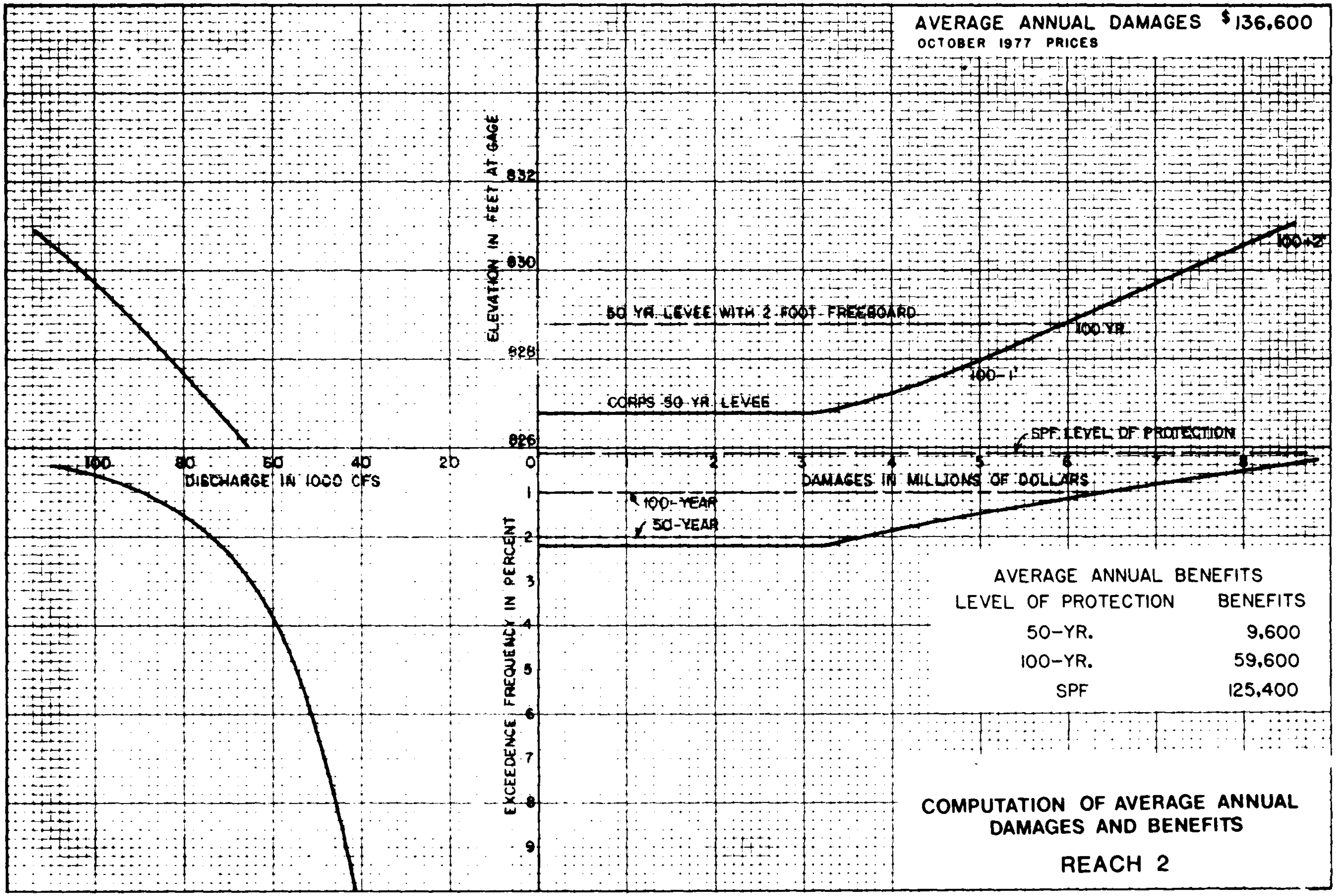
2 Average annual equivalent compound interest factor for 37 years of growth over 100-year economic life at 6 7/8 interest = 0.3436.

3 Average annual equivalent factor for 2-percent straight line growth for 50 years = 0.2988.



COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS
REACH 1

FIGURE A-1



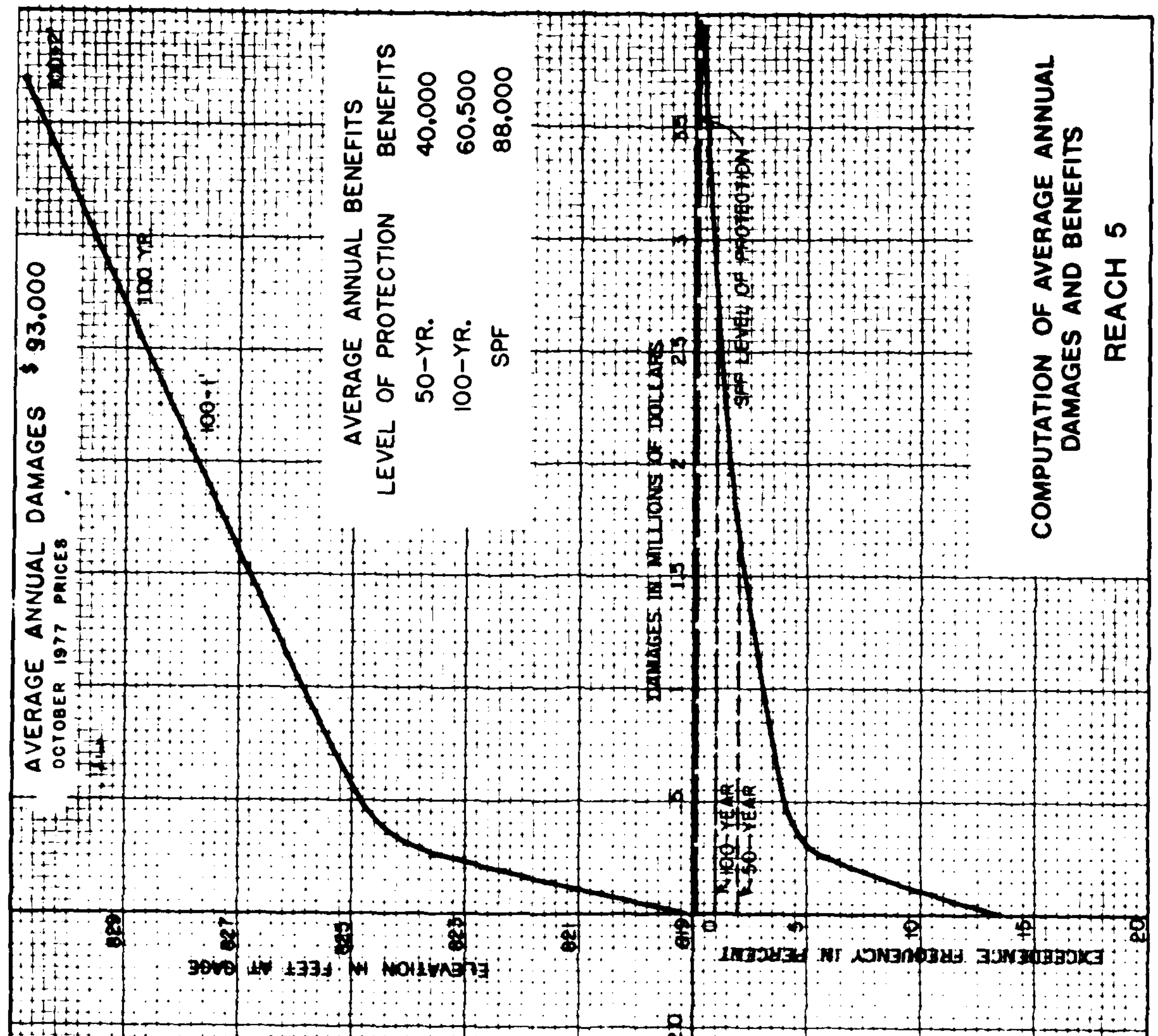
AVERAGE ANNUAL BENEFITS

LEVEL OF PROTECTION	BENEFITS
50-YR.	9,600
100-YR.	59,600
SPF	125,400

COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS

REACH 2

FIGURE A-2



AVERAGE ANNUAL DAMAGES $ 93,000
OCTOBER 1977 PRICES
AVERAGE ANNUAL BENEFITS
LEVEL OF PROTECTION BENEFITS
50-YR. 40,000
100-YR. 60,500
SPF 88,000
COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS
REACH 5
100 YR
100+1'
SPF LEVEL OF PROTECTION
100-YEAR
50-YEAR
DAMAGES IN MILLIONS OF DOLLARS
ELEVATION IN FEET AT GAGE
EXCEEDENCE FREQUENCY IN PERCENT
DISCHARGE IN 1000 CFS

FIGURE A-3

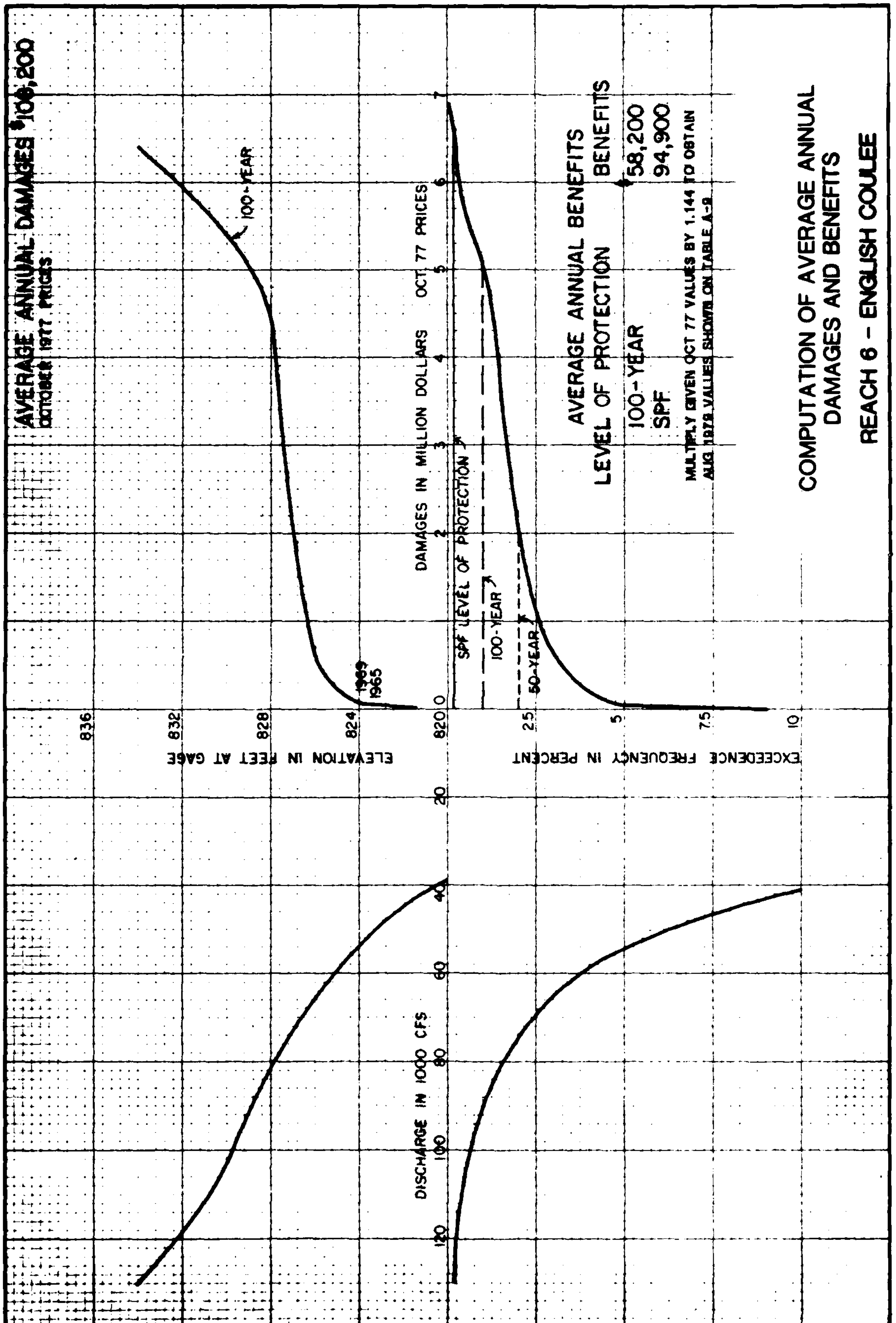

AVERAGE ANNUAL DAMAGES $106,200
OCTOBER 1977 PRICES
100-YEAR
1969
1965
DAMAGES IN MILLION DOLLARS OCT 77 PRICES
0
1
2
3
4
5
6
7
SPF LEVEL OF PROTECTION
100-YEAR
50-YEAR
ELEVATION IN FEET AT GAGE
820
824
828
832
836
EXCEEDENCE FREQUENCY IN PERCENT
2.5
5
7.5
10
DISCHARGE IN 1000 CFS
20
40
60
80
100
120
AVERAGE ANNUAL BENEFITS
LEVEL OF PROTECTION
BENEFITS
100-YEAR
$58,200
SPF
94,900
MULTIPLY GIVEN OCT 77 VALUES BY 1.144 TO OBTAIN AUG 1979 VALUES SHOWN ON TABLE A-9
COMPUTATION OF AVERAGE ANNUAL DAMAGES AND BENEFITS
REACH 6 - ENGLISH COULEE

FIGURE A-4

Table A-9 - Derivation of flood damage reduction benefits, Grand Forks (100-year)

Benefit category	Present conditions average annual damages	Remaining damages w/100-year level of protection	Present condition benefits	Year 2030 average annual benefits[1]	Net change in benefits (1980-2030)	Average annual equivalent of future growth	Total average annual benefits
Reach 1							
Residential	$ 78,770						
Public	1,080						
Comm. & Indust.	0						
Total	79,850	34,960	44,890	81,430	36,540	12,520[2]	57,410
Reach 2							
Residential	153,150						
Public	3,120						
Comm. & Indust.	0						
Total	156,270	88,090	68,180	123,750	55,570	19,010	87,190
Reach 5							
Residential	98,670						
Public	5,720						
Comm. & Indust.	2,000						
Total	106,390	37,180	69,210	125,060	55,850	19,020	88,230
Reach 6							
Residential	118,530						
Public	2,250						
Comm. & Indust.	3,000						
Total	123,780	57,200	66,580	119,580	53,000	17,950	84,530

1 Benefits projected to increase in proportion to average annual damages.

2 Residential and public benefits expected to accrue in proportion to growth of average annual damages and with each category annualized using appropriate average annual equivalent factor.

Table A-10 - Derivation of average annual benefits - Grand Forks Reaches 1, 2, 5 and 6

Reach and benefit category	Present condition average annual damages	Remaining damages w/ project	Present condition benefits	Benefits in year 2030	Benefit increase from 1980-2030	Average annual equivalent of future increase	Total average annual benefits
			50-year level of protection				
Reach 1	$ 79,850	$ 56,050	$23,800	$43,170	$19,370	$ 6,640	$30,440
Reach 2	156,270	145,290	10,980	19,930	8,950	3,070	14,050
Reach 5	106,390	60,630	45,760	82,640	36,880	12,560	58,320
Reach 6	123,780	86,260	37,520	67,380	29,860	10,230	47,750
			25-year level of protection				
Reach 1	79,850	70,930	8,920	16,180	7,260	2,490	11,410
Reach 2	156,270	-	0	0	0	0	0
Reach 5	106,390	84,370	22,020	39,790	17,770	6,060	28,080
Reach 6	123,780	103,990	19,790	35,540	15,750	5,400	25,190

Table A-11 - Determination of average annual benefits - Grand Forks-East Grand Forks study area (100-year degree of protection)

Benefit category	Present condition average annual damages	Remaining damages with 100-year level of protection	Present (1980) condition benefits	Benefits in year 2030[1]	Net change in benefits (1980-2030)	Average annual equivalent increase of future growth	Total average annual benefits
Grand Forks							
Residential	$434,800						
Public	74,600						
Industrial	718,900						
Total	1,228,300	$687,530	$540,770[2]	$728,420	$187,650	$63,030	$603,800
E. Grand Forks							
Residential	346,400						
Public	25,850						
Comm.-indust.	617,300						
Total	989,550	334,040	655,510[3]	871,830[4]	216,320	73,490	729,000
Total Grand Forks and East Grand Forks	2,217,850	1,021,340	1,196,280	1,600,250	403,970	136,520	1,332,800

1 2030 benefits = 1980 benefits x 1.347 (same proportionate increase as for average annual damages).
2 1977 benefits of $472,700 (sum of benefits for reaches 1 thru 6) x 1.144.
3 From stage 2 report benefits of $573,000 x 1.144 - includes reaches 1 and 3.
4 2030 benefits = 1980 benefits x 1.330.

Table A-12 - Determination of average annual benefits - Grand Forks-East Grand Forks area

City	Present condition average annual damages	Remaining damages for 50-year level of protection	Present condition benefits (1980)	Benefits in year 2030	Net change in benefits (1980-2030)	Average annual equivalent increase of future growth	Total average annual benefits
Grand Forks	$1,228,300	$ 942,870	$285,430	$384,480	$ 99,050	$ 33,270	$318,700
East Grand Forks	989,550	506,750	482,800	642,100	159,300	54,100	536,900
Total	2,217,850	1,449,620	768,230	1,026,580	258,350	87,370	855,600
Grand Forks	1,228,300	1,153,400	74,900	100,890	25,990	8,700	83,600
East Grand Forks	989,550	766,450	223,100	296,720	73,620	25,000	248,100
Total	2,217,850	1,919,850	298,000	397,610	99,610	33,700	331,700

1 1980 benefits = October 77 benefits updated to August.
2 1979 price levels (factor = 1.144). Composite curve used.

Table A-13 - Summary of average annual benefits

Area	Grand Forks reaches 100-year	50-year	25-year
Reach			
1	$57,410	$30,440	$11,410
2	87,190	14,050	0
5	88,230	58,320	28,080
6 (English Coulee)	84,530	47,750	25,190

Entire Grand Forks-East Grand Forks study area

City			
Grand Forks	603,800	318,700	83,600
East Grand Forks	729,000	536,900	248,100
Total	1,332,800	855,600	331,700

DETERMINATION OF TOTAL BENEFITS - REACH 6

Table A-9 and plate A-4 indicate a present condition 100-year benefit for Reach 6 of $66,580. Similarly, table A-10 shows a 50-year present condition benefit of $37,520. These values were determined using Octo r 1977 flood damage data updated to August 1979 price levels and are the result of reductions in damages attributable to Red River of the North backup only.

The April 1979 flood demonstrated that flood damages along the English Coulee were not only caused by Red River of the North backup but also high flows down the coulee itself. Hydrologic and hydraulic studies and detailed flood damage surveys in the upper portion of the coulee showed that substantial flood damages could occur upstream of the DeMers Avenue Bridge as a result of high coulee flows.

The stage 3 economic studies indicated that average annual flood damages for the coulee reach upstream of the Burlington Northern railroad bridge (near DeMers Avenue as shown on figure 2) resulting from high coulee flows would be approximately $252,000. Because Red River of the North backwater has little effect on flood levels in this area, related damages would be minor and, thus, were not evaluated for this analysis. Similarly, the effect of high coulee flows downstream of the Burlington Northern railroad bridge superimposed on effects of Red River backwater would also be relatively minor (because of significant discharge and stage reductions at the bridge) and was disregarded.

The considered closure structure at Mill Road would only reduce those damages attributable to Red River backup, which are estimated at $123,780 (present condition) as shown on table A-7. Related average annual 100-year flood damage reduction benefits, including allowances for estimated future damage growth, would be $84,530 as shown on table A-9.

The considered flood proofing and evacuation alternative for Reach 6 would reduce recurring flood damages from both Red River backup and high flows from the coulee drainage area. Flood damage reduction benefits

attributable to the high coulee flow situation were determined with the assumption that a recently completed raise of South 30th Street together with an effective closure across DeMers Avenue and temporary interior drainage measures would substantially reduce the flood damage potential. These measures were assumed to provide a 100-year level of protection to property located east of the barrier. Remaining 100-year flood damages in the unprotected areas upstream of the Burlington Northern railroad bridge would be reduced from $250,000 to $65,000. The considered flood proofing and evacuation measures would further reduce these damages by $33,800 (100-year flood level) for a 100-year average annual present condition benefit of $31,200. Total average annual benefits attributable to reduction of damages from both flooding conditions (including the effects of the affluence factor) would be $124,800 and $83,050 for the 100-year and 50-year levels of protection, respectively.

ATTACHMENT B

PRELIMINARY ASSESSMENT

OF

LEVEE STABILITY

ATTACHMENT B

PRELIMINARY ASSESSMENT

OF LEVEE STABILITY

SUMMARY

Movement of the riverbanks at various locations in the Grand Forks area has been documented since 1910. The instability has been precipitated by both manmade loadings and natural erosion processes. The primary cause of the earth movements is the presence of a foundation deposit of weak glacial lake clay. While this unit is known to underlie the majority of the Grand Forks area, river erosion has completely or partially removed this deposit in several areas adjacent to the river. In these areas, the subsurface deposits are generally stronger and less likely to undergo movements when loaded with earth fills. Because subsurface data are lacking on most of the study area, the foundation profile was inferred on the basis of U.S. Geological Survey topography which indicates general surface erosion patterns. On the basis of inferences regarding the subsurface profile, it was concluded that (1) a levee raise of the permanent project earth fill is judged to be at least marginally feasible, (2) the natural riverbanks upstream and downstream of the permanent project have a high potential for earth movement if earth fill is placed close to the river, and (3) the construction of levees in the Riverside Park area may be feasible, but extreme care should be taken in siting the upstream and downstream tiebacks.

Because definitive subsurface information is lacking, the above conclusions should be viewed as very preliminary and should be verified by subsurface analysis at an early stage in project planning.

GENERAL DESCRIPTION OF AREA

SCOPE OF ASSESSMENT

The conclusions and evaluation in this report represent a preliminary assessment of the technical feasibility of constructing or raising earth

levees at various areas along the Red River in Grand Forks, North Dakota. In many areas, subsurface data are fragmentary or nonexistent. The results and conclusions of this study, therefore, can only be treated as an educated guess at the subsurface conditions and problems associated with placement of earth fill along the banks of the Red River.

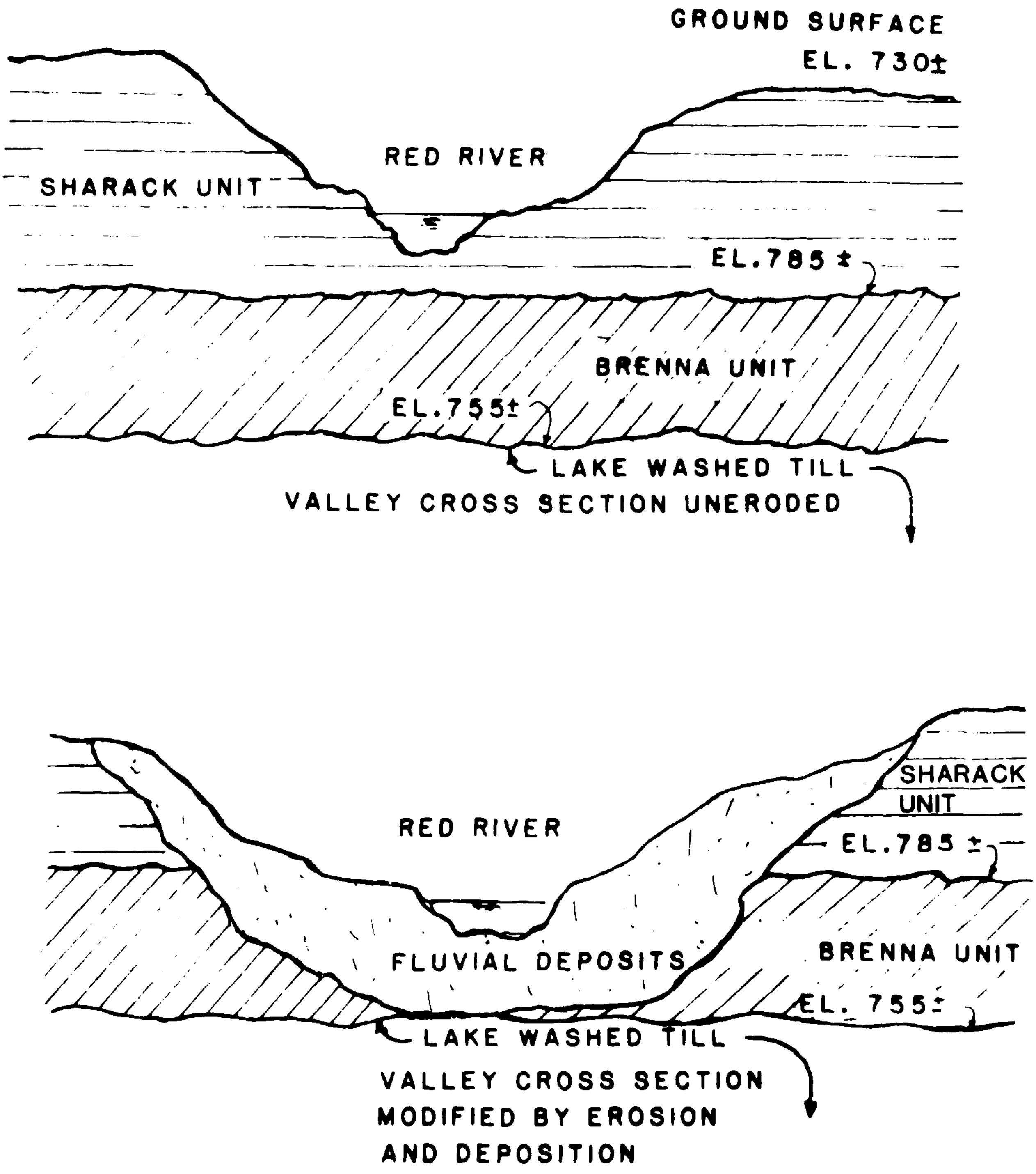
SUBSURFACE INFORMATION

Available subsurface information included numerous borings and laboratory testing done during 1949-50 and 1954 in conjunction with the permanent levee project in Grand Forks. Subsurface information in the East Grand Forks area was available from the General Design Memorandum, Grand Forks-East Grand Forks dated May 1953. The history of earth movements was obtained from various Corps of Engineers memorandums and visual observations made from 1968-1979. The terminology used to describe the various deposits in the Grand Forks area was obtained from unpublished notes of Steven Brophy, North Dakota Geological Survey.

SUBSURFACE PROFILE

The character and configuration of the subsurface profile in the Grand Forks area have a major influence on the occurrence of earth slides. The subsurface deposits in the Grand Forks area are a product of the last glacial age when northward drainage of the Red River was blocked by the retreating glacial ice mass. This blocked drainage resulted in the formation of Lake Agassiz. Most of the upper subsurface deposits in the Grand Forks area were deposited in this lacustrine environment. The top illustration in figure B-1, shows the unaltered lacustrine deposits. The major units in this subsurface profile consist of the following:

1. Sharack Unit (ground surface to elevation 785±)
   This unit consists of a laminated clay unit with moisture contents of 30 to 50 percent and liquid limits of 60 to 80 percent. The clay in this deposit is laminated with silt lenses which are capable of



Typical Valley Cross Sections

Figure B-1

carrying groundwater. This unit is generally believed to have been deposited in a shallow water environment during the later stages of Lake Agassiz. In general, the Sharack Unit represents a relatively competent deposit with undrained shear strengths of 700 to 1,200 psf (pounds per square foot) or more.

2. Brenna Unit (elevation 785± to 755±)
The Brenna Unit may be considered as the "bad actor" in the subsurface profile. This unit was originally deposited during the deepwater phases of Lake Agassiz. A former drying surface has been identified in the upper portions of the Brenna Unit. The drying surface is believed to represent an intermittent period of geological history when the glacial lake was temporarily drained. The Brenna Unit is composed of massive clay deposits with moisture contents of 50 to 80% and liquid limits from 90 to 130%. Void ratios range from 1.7 to 2.3. The Brenna Unit may be considered as a very weak deposit with undrained shear strengths in the range of 400 to 500 psf. The presence of this unit is responsible for the large number of earth movements which have occurred along the Red River in the area of Grand Forks.

3. Lake Washed Till (elevation 755± and below)
The unit underlying the Brenna deposit has been classified as lake washed till. In comparison to the Sharack and Brenna Units, this deposit is relatively strong and the top of this unit represents a lower boundary for earth movements.

EFFECT OF EROSION ON THE SUBSURFACE PROFILE

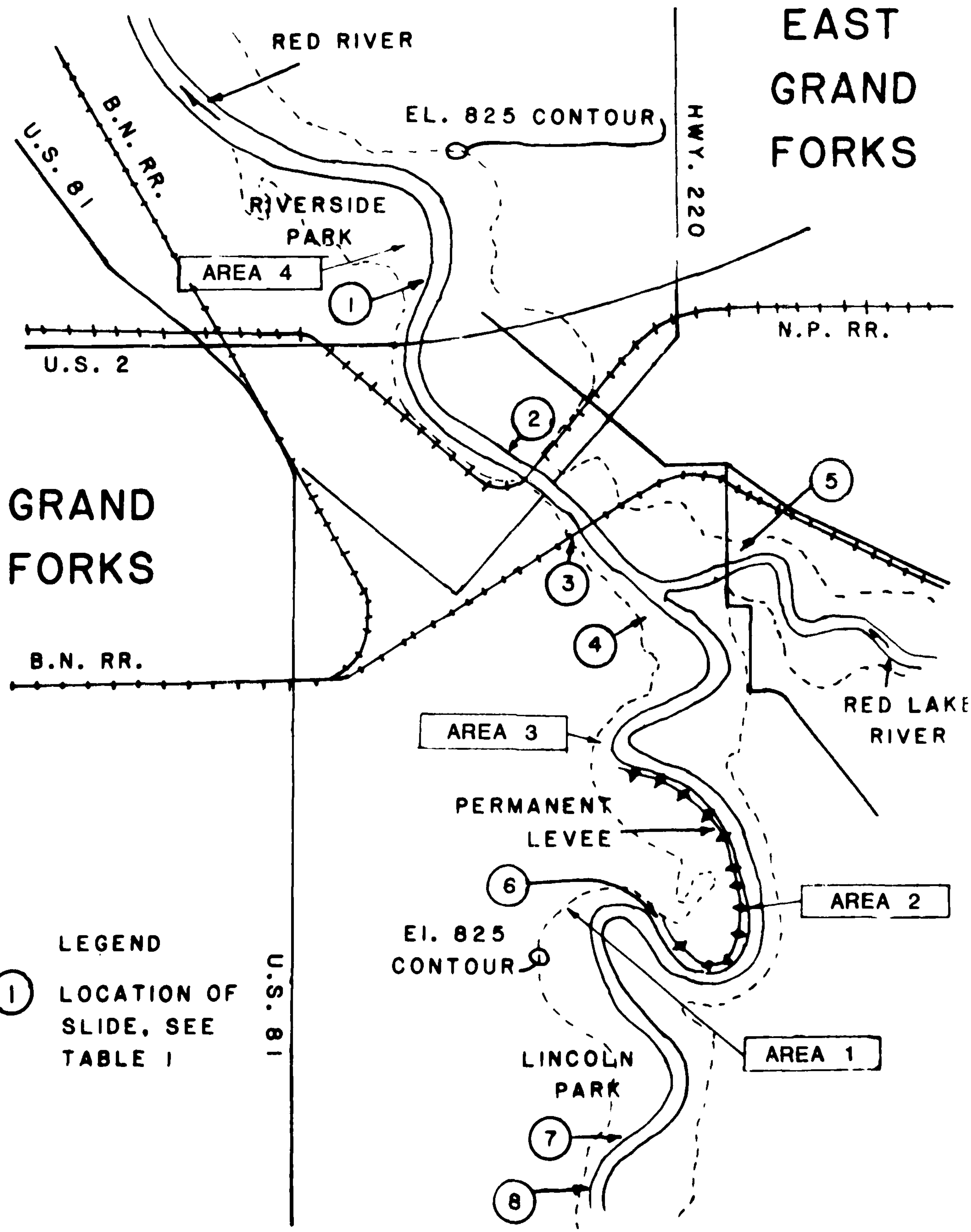
At some time after the recession of Lake Agassiz, the Red River scoured out the lacustrine deposits in many areas adjacent to the river and redeposited fluvial (river) deposits in their place. The final product of this process is shown in the bottom illustration of figure B-1. As a result of this erosion and deposition process, the thickness of the weak Brenna Unit varies along the Red River from approximately 0 to 30 feet. The fluvial deposits consist of predominantly silt and

and clay material with traces of organic material. In strength characteristics, the fluvial deposits are generally comparable to the Sharack Unit and stronger than the Brenna formation. Therefore, in areas where the Brenna Unit has been eroded and replaced by fluvial deposits, the subsurface profile is much more capable of sustaining the loads imposed by earth fills.

A general assessment of the stability characteristics of the various reaches of the Red River in the Grand Forks area depends to a large extent on the identification of the areas where the full thickness of the Brenna Unit is present. Because the Red River has an extremely small flow gradient, it has historically exhibited a tendency to meander. Remnants of abandoned oxbows attest to the meandering characteristics of the river. Figure B-2 shows a map of the Grand Forks area upon which the 825 msl contour has been superimposed. The 825 contour is significant because it represents the approximate elevation of the uneroded surface of the flat plains on either side of the river. Areas between the 825 contour and existing shore of the river (elevation 792±) may be assumed to have been at least partially eroded by the river. The presence of at least some subsurface fluvial deposits and favorable foundation conditions may therefore be inferred in areas where the 825 contour is located at relatively large distances from the river.

HISTORY OF EARTH MOVEMENTS

The use of the 825 contour to identify subsurface fluvial deposits is at best a very broad generalization which, in specific areas, must be substantiated by subsurface investigations. However, the general validity of using the 825 contour to identify fluvial deposits and favorable foundation conditions is illustrated by the data contained on figure B-2 and table B-1 which show the location of previous earth movements documented in the Grand Forks area. It may be noted that virtually all the movements occurred in areas where the 825 contour is relatively close to the river.



LOCATION OF STUDY AREAS

Figure B-2

Table B-1 - Description of previous earth movements

1. RIVERSIDE PARK EMERGENCY LEVEE. Slide started in 1972 and movement increased after addition of more emergency levee fill in 1976. The slide is active and moving.

2. EAST GRAND FORKS EMERGENCY LEVEE. Slide is located behind houses located on riverward side of North First Street near Third Avenue North. The slide is active.

3. GREAT NORTHERN RAILWAY BRIDGE. This movement ocurred in 1910 during construction of the abutment for the bridge. Subsequent unloading and construction of a long timber trestle in lieu of earth fill have apparently stabilized the area.

4. CITY WATERWORKS. This slide, which ocurred in 1946, was caused by the addition of dump and debris material landward of the water storage tank. The slide area appears stable.

5. MINNESOTA AVENUE BRIDGE IN EAST GRAND FORKS. The right abutment of this bridge has slumped from 3 to 4 feet and has extended into a parking lot adjacent to the bridge. This slide is active.

6. SLIDE AT UPSTREAM END OF CORPS LEVEE. This slide occurred in 1954 and necessitated relocation of homes, unloading of the river slopes, and installation of approximately 400 feet of floodwall. The slide is inactive.

7. GRAND FORKS RECREATION BUILDING. This structure straddles an active slide which was first noted in 1969. The building has been severely cracked and displaced, and the lower level is unusable.

8. ELKS CLUB PARKING LOT. This slide appears to be active and has caused vertical displacements of about 2 feet in the parking lot.

The significance of fluvial deposits to the stability of earth structures is best illustrated by the construction history of the permanent levee project at Grand Forks. The construction of the flood protection required approximately 20-foot levee fills along the majority of the barrier alignment. Borings indicate the presence of fluvial deposits in this area. No difficulty was encountered until a low 6-foot fill was constructed on the south end of the project (where the 825 contour

was close to the river). Because the thickness of the Brenna Unit in this area is 35 feet, a large slide was initiated which required the construction of a floodwall and a 2-year delay in completion of the project.

EVALUATION OF NEW LEVEE CONSTRUCTION OR LEVEE RAISES

GENERAL

The technical feasibility of levee construction was assessed at four locations. These four locations are shown on figure B-2 and are numbered from upstream to downstream. At areas 1, 3, and 4, the assessment is somewhat subjective because subsurface information is not available. At area 2, enough data were available to merit a preliminary stability analysis. In all areas, it was assumed that the top elevation of the levee would be 835.6± and that the natural riverbank was presently stable. The stability of the natural riverbank is an extremely important item which should be verified by detailed field inspection. The conclusions given below are based on broad generalizations and are intended to serve only as a guide for preliminary planning. It is recommended that these conclusions be verified by subsurface investigations at an early point in the planning and design process.

AREA 1 (UPSTREAM OF PERMANENT PROJECT)

A raise of the permanent project levee would require an extension of the levee in the vicinity of area 1. This area is very close to the location where the 1953 slide took place. Examination of figure B-2 indicates that the 825 contour is relatively close to the river which indicates the probable presence of an adverse foundation profile. On the basis of these two factors, the addition of earth fill in this area would create a high probability for failure of the riverbanks. Therefore, it is recommended for planning purposes that a floodwall be considered for this area or that the levee alignment be located well landward of the river. The use of a floodwall would only be feasible if the existing natural slope is stable.

AREA 2 (PERMANENT PROJECT)

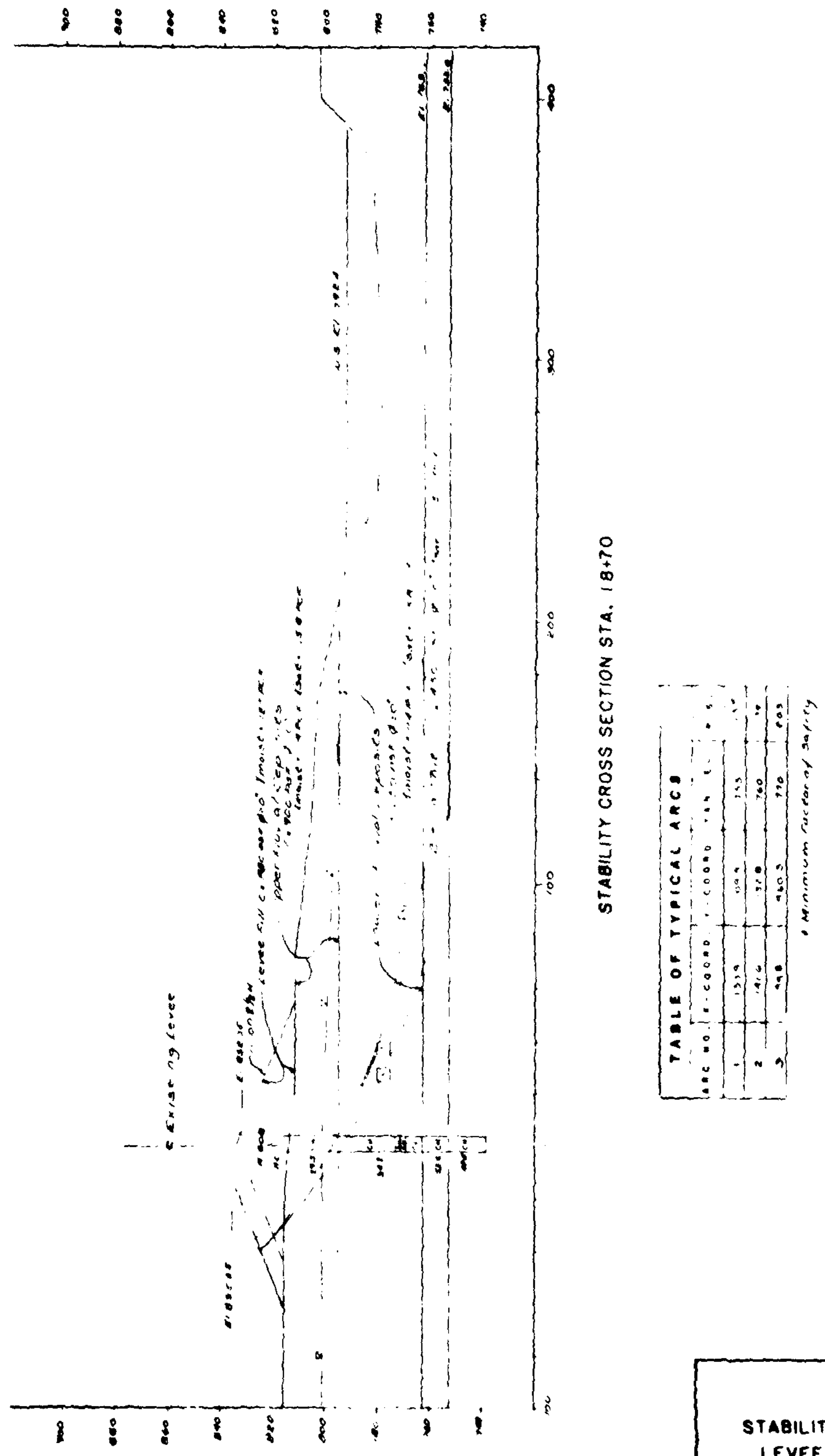
An increase in the height of the permanent project levee was analyzed using data contained in "Report on Foundation Investigations Made Subsequent to Slide at Upstream End of Grand Forks, North Dakota Levee," prepared by the St. Paul District, Corps of Engineers. A levee cross section shown on figure B-3 was analyzed for the end of construction case using the Corps' circular arc stability program 741-030. The soil parameters used in the analysis were identical to those utilized in the 1954 study. The results of the analysis indicate that the factor of safety for the existing levee is 1.26. As shown on figure B-3, the levee raise decreases the factor of safety to 1.13. Neither factor of safety meets the required value of 1.30. However, the analysis and parameters shown on figure B-3 did not include the effects of any time-dependent increase in strength. It is probable that the loading of the existing levee fill and attendant consolidation have caused some strength gain in a portion of the foundation deposits. Therefore, the analysis shown on figure B-3 is conservative and future drilling, testing, and analysis would result in factors of safety which approximate 1.3 or more. For this reason, a raise of the majority of the existing levee section is potentially feasible from a stability standpoint.

AREA 3 (DOWNSTREAM OF PERMANENT PROJECT)

An extension of the levee fill on the downstream end of the permanent project would involve a relatively high risk of failure unless the alignment is located well away from the river. As shown on figure B-2, the 825 contour is located close to the river in this area, and it is therefore probable that a relatively weak subsurface profile is present. It is recommended that a stub floodwall (no base or sheet piling) be considered in this reach if the alignment lies close to the river.

AREA 4 (RIVERSIDE PARK AREA)

Construction of a levee in the Riverside Park area may be feasible depending on the height and location. On the basis of the topography, a favorable foundation profile probably exists in a large part of the area. However, a recent slide occurred (No. 1, figure B-2) in the upstream area of this reach. The slide was located in an area where the 825 contour was relatively close to the river, indicating the presence of the weak Brenna Unit. While levee construction is probably feasible, the locations of upstream and downstream levee tiebacks in this area are particularly critical and should be based on a detailed assessment of foundation conditions.



STABILITY OF EXISTING
LEVEE WITH RAISE

FIGURE B-3

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TABLES

FIGURES

ATTACHMENTS

URBAN DRAINAGE MASTER PLAN
GRAND FORKS, NORTH DAKOTA

INTRODUCTION

Grand Forks, North Dakota, has three major drainage problems: (1) local flooding and temporary impoundment of runoff because of inadequate drainage facilities, (2) overflow of the combined wastewater and storm sewer system during heavy rainfalls, and (3) frequent flooding caused by high flood stages on the Red River of the North. These problems were identified in the Grand Forks-East Grand Forks Urban Water Resources Study, Stage 2 Floodplain Management Appendix completed by the Corps of Engineers (Ref. 1). The Floodplain Management Appendix recommends that a master drainage plan be developed for Grand Forks and a 2-mile fringe around the city.

In accordance with the above recommendation, this report presents two drainage plans designed to minimize urban flooding in Grand Forks and to serve as a base for an overall flood control plan for the city for the year 2030. The costs of the drainage plans and the impacts of each plan on flooding within the study area are reviewed in the report, and one of the options is recommended for implementation by Grand Forks. The proposed drainage plans were formulated and analyzed on the basis of their conformance to the following objectives of stormwater management:

- Minimize existing and future adverse impacts of storm drainage.
- Provide a drainage plan with maximum net economic efficiency.
- Enhance and preserve the quality of the environment.
- Stimulate an orderly and systematic water and related land use plan within the study area.
- Develop a staged drainage plan consistent with the growth objective of the study area and adjacent areas.

STUDY AREA

STUDY BOUNDARIES

As shown on the location map (figure 1), Grand Forks is in northeastern North Dakota approximately 298 miles upstream of the mouth of the Red River (Lake Winnipeg). The study area consists of approximately 33 square miles of undeveloped and developing land outside the sewered portion of the city and within the city's 2-mile limit of zoning jurisdiction. The inner and outer study boundaries are shown on the study area map (figure 2). The southern edge of the outer study boundary extends south 1 mile beyond the zoning limit between the Red River and Interstate 29. Areas within the sewered portion of the city were considered in the study to the extent that they affect drainage within the study area.

POPULATION

Grand Forks had a population of 42,581 in 1976; the city's projected population for the year 2000 is 62,900 (Ref. 2). The Grand Forks City Planning Office projects a slowed growth rate after 2000 to a population of about 75,000 by the year 2030. This estimate is based on a uniform growth rate of 433 persons per year after the year 2000, a rate 27 percent lower than that which occurred in 1975 and 1976 and about 45 percent lower than the estimated growth rate for 1976 through 2000.

LAND USE

The existing land use for Grand Forks is shown in figure 3; the city's future land use plan for the year 2000 is shown in figure 4. These figures were developed by the Grand Forks City Planning Office and the North Dakota State Highway Department. It was assumed that areas zoned for commercial, industrial, and residential development in 2000 (figure 4) will be fully developed for such uses by the year 2030 and that areas zoned as vacant and undeveloped (agricultural) will be developed to the extent that 20 percent of the areas will be impervious by 2030. Projected land use for 2030 for subwatersheds within the study area is summarized in table 1.

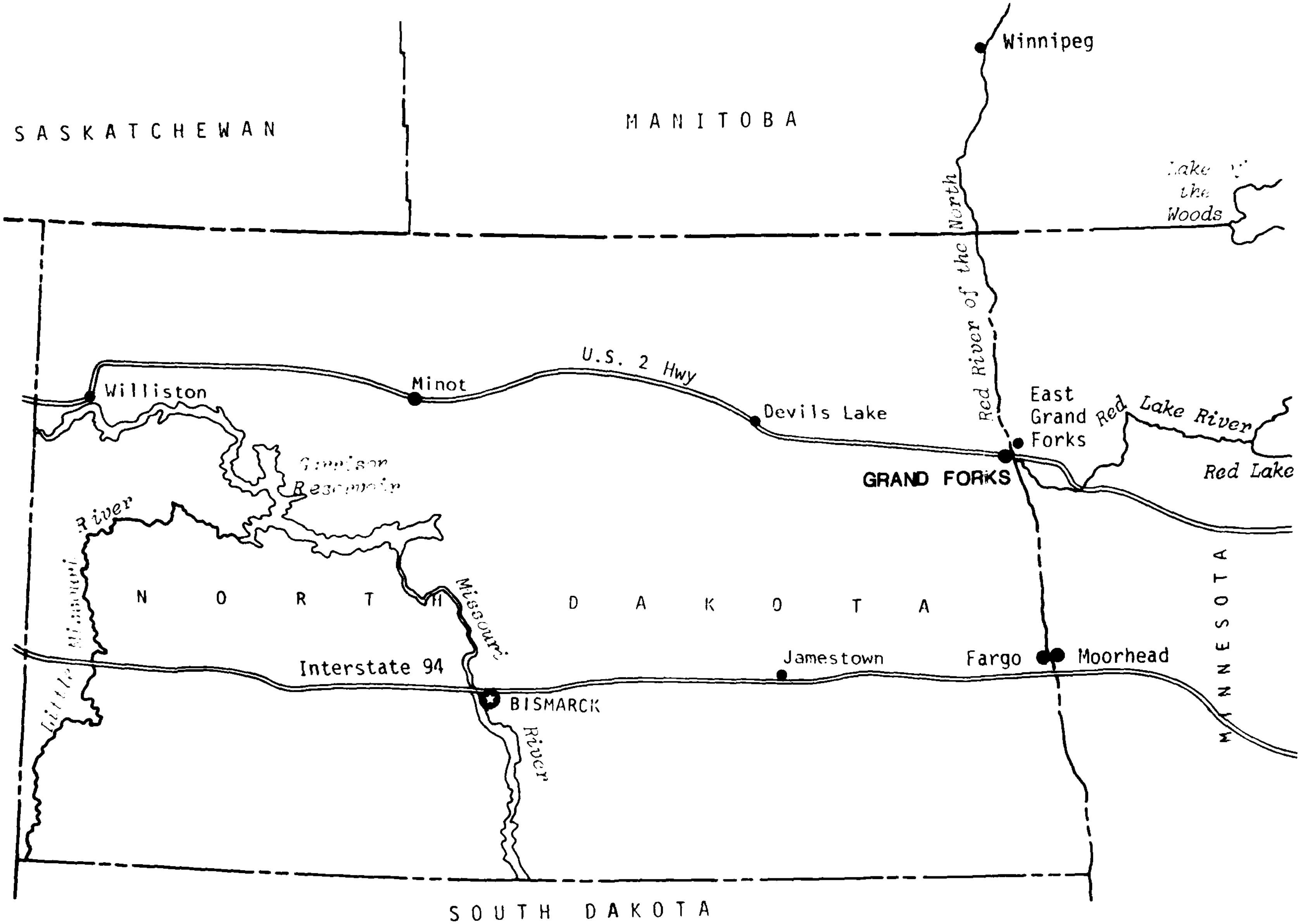


FIGURE 1
LOCATION MAP
URBAN DRAINAGE MASTER PLAN
Grand Forks, North Dakota

Barr Engineering Co.
Minneapolis, Minnesota

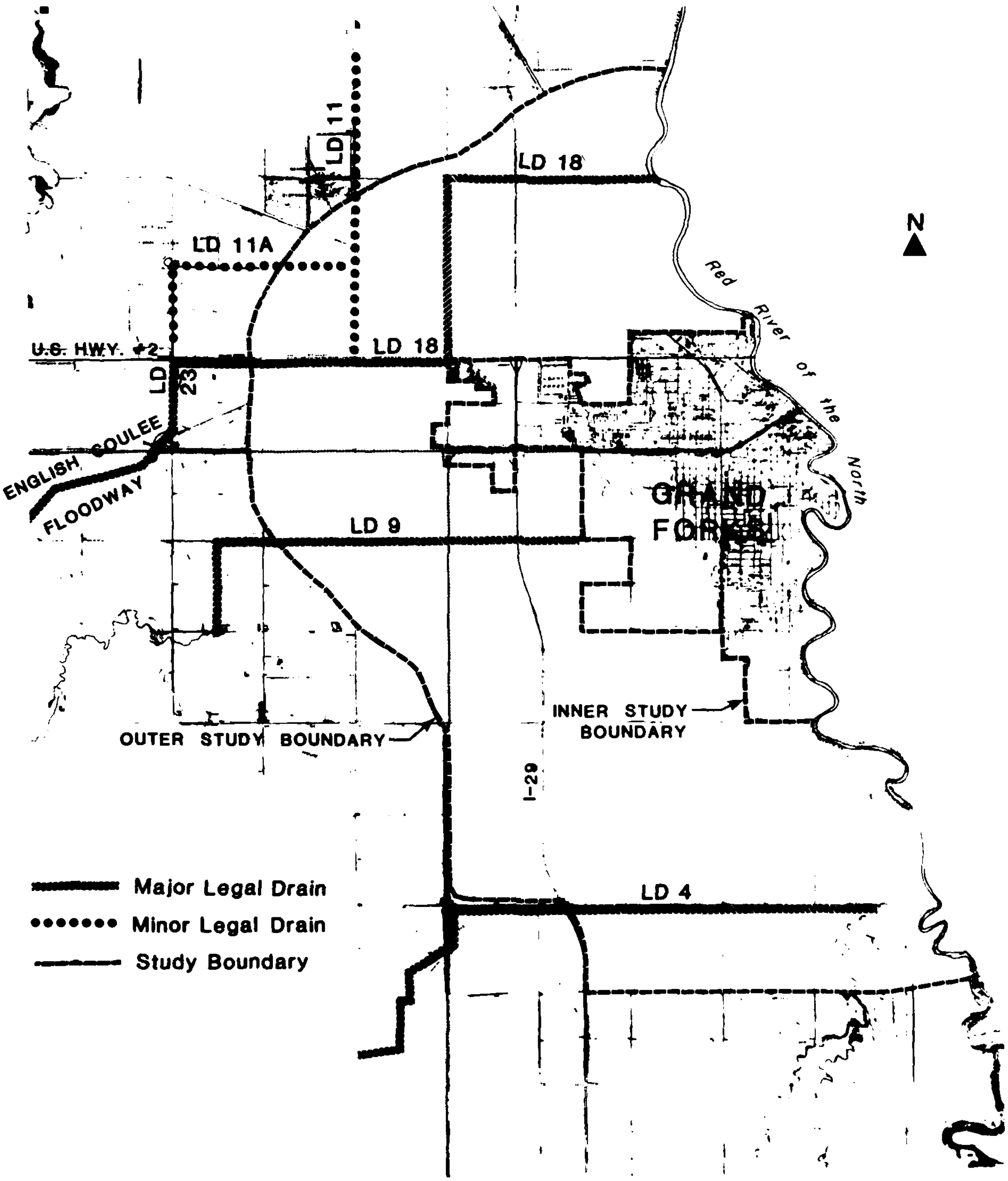


FIGURE 2

STUDY AREA MAP

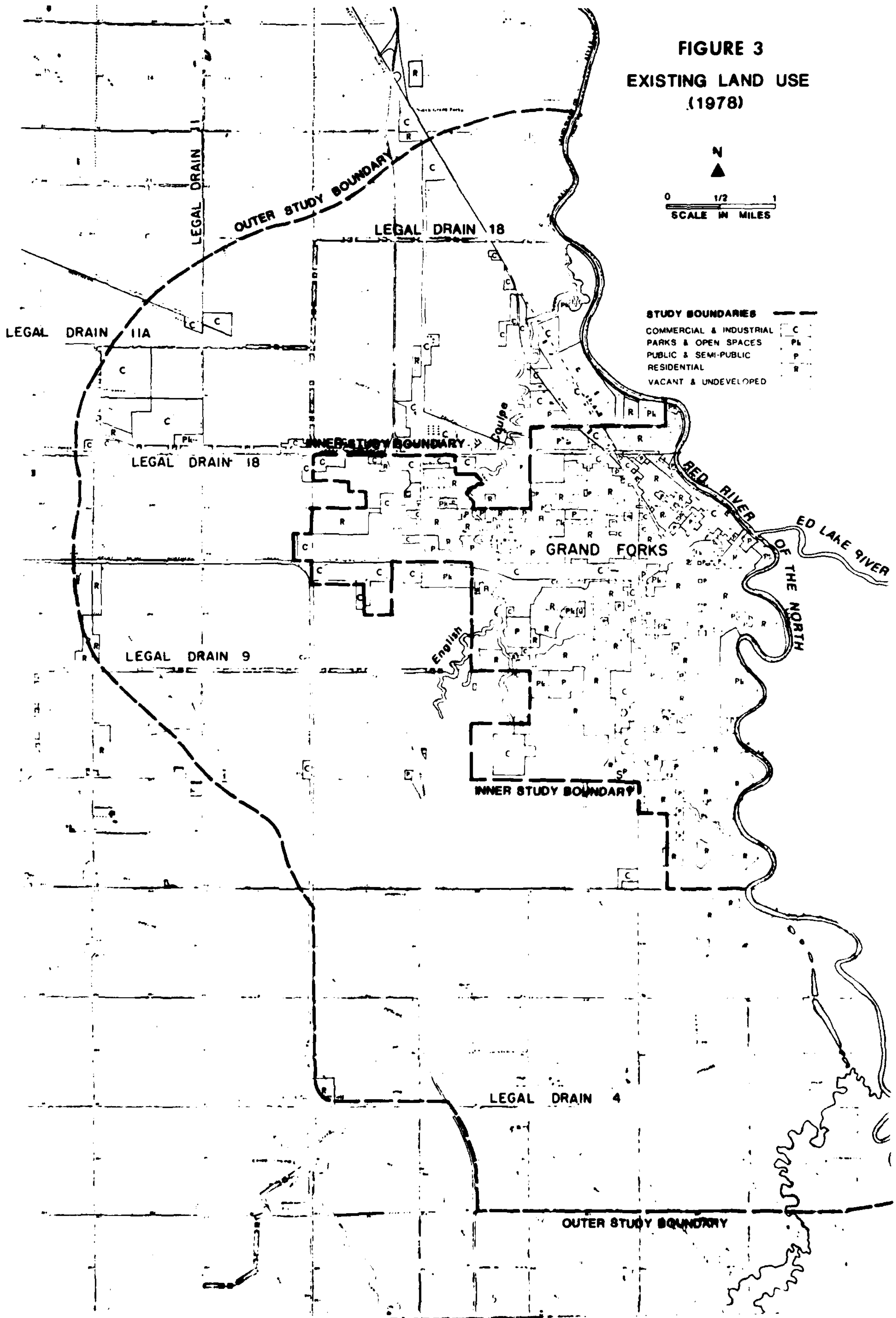


FIGURE 3
EXISTING LAND USE
(1978)
N
0 1/2 1
SCALE IN MILES
STUDY BOUNDARIES
COMMERCIAL & INDUSTRIAL C
PARKS & OPEN SPACES Pk
PUBLIC & SEMI-PUBLIC P
RESIDENTIAL R
VACANT & UNDEVELOPED
OUTER STUDY BOUNDARY
INNER STUDY BOUNDARY
LEGAL DRAIN 18
LEGAL DRAIN 11A
LEGAL DRAIN 9
LEGAL DRAIN 4
GRAND FORKS
RED RIVER OF THE NORTH
RED LAKE RIVER
English
Coulee

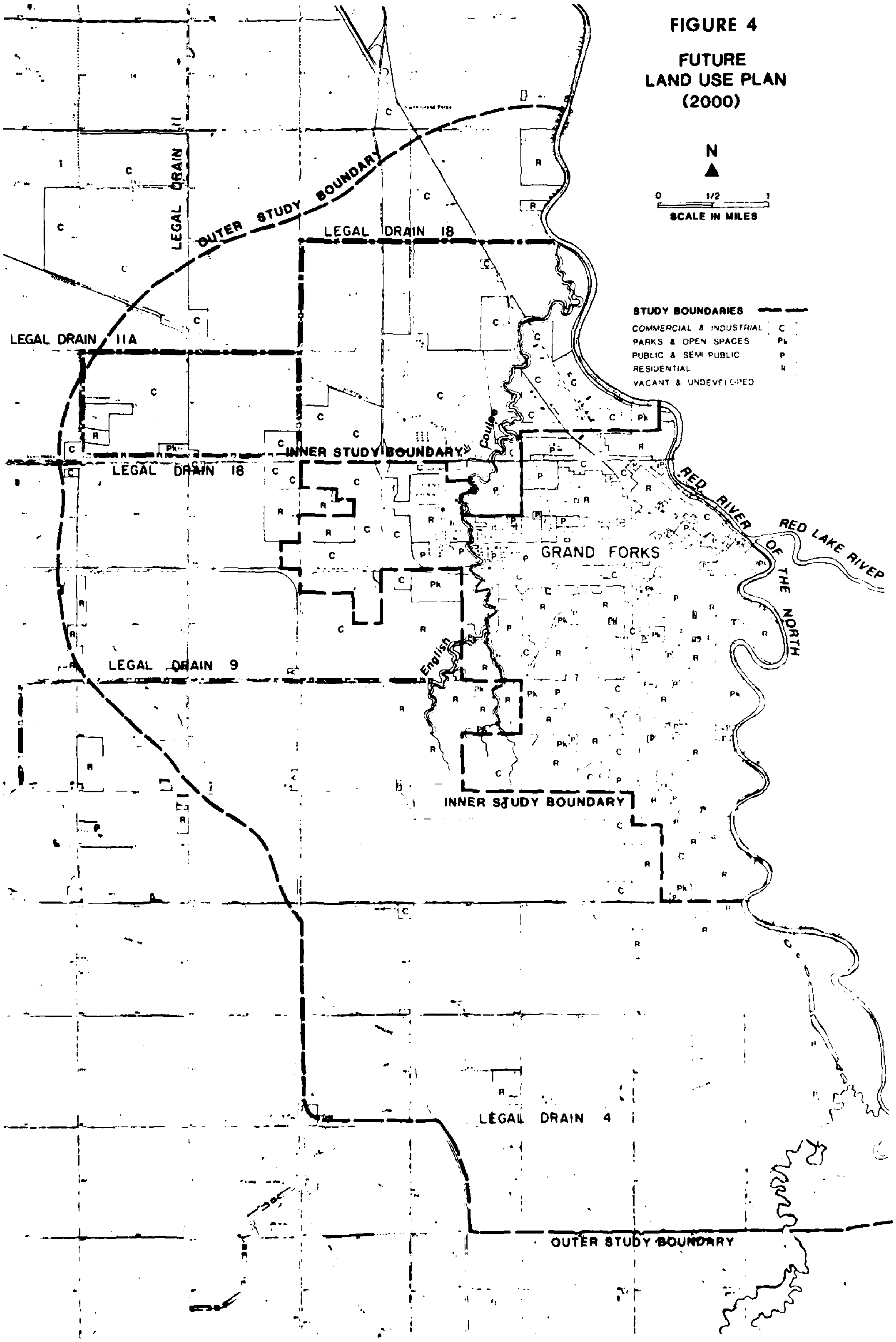


FIGURE 4
FUTURE LAND USE PLAN (2000)
N
0
1/2
1
SCALE IN MILES
STUDY BOUNDARIES
COMMERCIAL & INDUSTRIAL C
PARKS & OPEN SPACES Pk
PUBLIC & SEMI-PUBLIC P
RESIDENTIAL R
VACANT & UNDEVELOPED
OUTER STUDY BOUNDARY
INNER STUDY BOUNDARY
LEGAL DRAIN 11
LEGAL DRAIN 11A
LEGAL DRAIN 18
LEGAL DRAIN 9
LEGAL DRAIN 4
GRAND FORKS
RED RIVER OF THE NORTH
RED LAKE RIVER
English Coulee

Table 1: Future land use distribution (2030)

Area Name*	Total Area, Acres	Land Use Distribution, Acres[1] A	B	C	D
A1	241	241	-	-	-
A2	428	268	-	-	160
A3	395	312	-	-	83
A4	297	241	-	-	56
A5	520	520	-	-	-
A6	634	565	-	-	69
A7	116	116	-	-	-
A8	264	44	-	-	220
A9	579	504	-	-	75
A10	231	114	-	-	117
A11	652	552	-	-	100
A12	628	623	-	-	5
A13	674	664	-	-	10
A14	587	567	-	-	20
A15[2]	10[3]	-	-	-	-
B1	313	18[4]	10	20	265
B2	56	11	-	-	45
B3	130	-	-	-	130
B4	52	42	-	-	10
C1	284	164	85	15	20
C2	48	-	-	-	48
C3	493	-	-	-	493
C4	632	607	-	-	25
D1	214	179	35	-	-
D2	322	261	33	8	20
D3	638	625	10	3	-
D4	663	658	-	-	5
D5	613	613	-	-	-
D6	480	480	-	-	-
D7[2]	8	-	-	-	-
D8[2]	8[3]	-	-	-	-
E1	96	84	12	-	-
E2	206	166	23	-	17
E3	630	630	-	-	-
E4	163	163	-	-	-
E5	697	697	-	-	-
E6	697	697	-	-	-
E7	242	242	-	-	-
E8	192	192	-	-	-
E9	480	451	-	-	29
E10	480	451	-	-	29
E11	706	706	-	-	-
E12	680	668	-	-	12
E13	640	640	-	-	-
E14	640	640	-	-	-
E15	615	615	-	-	-

Table 1: Future land use distribution (2030) (cont)

Area Name*	Total Area, Acres	Land Use Distribution Acres[1] A	B	C	D
F1	56	56	-	-	-
F2	330	330	-	-	-
F3	371	371	-	-	-
F4	609	609	-	-	-
F5	539	539	-	-	-
F6[2]	32	-	-	-	-
G1	1,853	1,568	280[5]	-	5
H1	121	16[4]	10	75	20
H2	821	551[6]	55	60	155
H3	418	133	58	12	215
H4	320	136	19	27	138
H5	320	280	-	-	40
H6	331	176	-	-	155
I	241	135[7]	10	15	81
J	175	85[6]	-	45	45
K	901	335[8]	40	361	165
L	603	106	20	-	477
M	201	9	10	5	177
N	194	154	20	-	20

[1] A = Residential (single-family, except where noted otherwise), B = Park and Recreation (including open space), C = Public and Semi-Public, D = Commercial and Industrial.

[2] Land use is agricultural.

[3] Represents tributary area downstream of the diversion structure.

[4] Includes 5 acres multiple-family residential.

[5] Includes 10 acres open water.

[6] Includes 70 acres multiple-family residential.

[7] Includes 65 acres multiple-family residential.

[8] Includes 40 acres multiple-family residential.

*Areas labeled on figures 8 and 9.

There are minor differences in the land use information presented in figures 3 and 4 of this report and the information presented in maps 3 and 11 of the Year 2000 Land Use Plan, Grand Forks, North Dakota (Ref. 3) since the latter information was not received until after the submittal of the preliminary draft of this report. The Land Use Plan was reviewed, however, and the differences in land use would have no significant impact on the results of the study presented here.

GROUNDWATER

Grand Forks County, North Dakota, lies near the eastern edge of a large, complex regional groundwater system that originates many miles to the west (Ref. 4). The major areas of recharge for this system are in the topographically high areas in the western part of the county and in regions farther west. Groundwater flows east and northeast from the recharge areas to an artesian discharge basin in the lower, eastern portions of the county.

Grand Forks is underlain by water-bearing sand and gravel at a depth of about 200 feet (Ref. 4). This stratum, commonly known as the Grand Forks aquifer, has an areal extent of about 20 square miles in North Dakota with additional unquantified area in Minnesota. The aquifer is generally less than 20 feet thick; its greatest known thickness is 25 feet in the western portion of the city. Glacial deposits of clay and till are interspersed locally with the sandy (fine- to medium-grained), poorly sorted gravels of the Grand Forks aquifer.

A preliminary review of local groundwater and soils data indicates that flooding in the study area is not caused by high groundwater levels. Groundwater tables as high as 3 to 5 feet below the surface have been reported in various locations, but the location and fluctuation of these table. have not been documented. However, the potential for high groundwater problems should be investigated whenever open ditches or ponding areas are considered as part of the local drainage system. Clays and silts at various depths in the Grand Forks area may cause subsurface water to accumulate and reduce the rate of infiltration or routing of infiltrated water into the urban drainage system. Reduced infiltration and seepage rates cause higher volumes of direct runoff, thereby increasing the potential for local flood problems.

TOPOGRAPHY AND GEOLOGY

Eastern Grand Forks County and the city of Grand Forks are on the relatively flat Lake Agassiz plain, a landform modified only by a few ridges and scarps. The area slopes northeast toward the Red River at a gradient generally less than 0.09 percent (Ref. 4), although local slopes vary from 0.06 to 0.19 percent (Ref. 5). The extreme eastern part of the county, including Grand Forks, is very poorly drained, and numerous intermittent streams terminate in the flat lake plain near the city. Several ditches have been constructed to extend drainage to the Red River, but serious storm drainage problems still exist. Elevations in the vicinity of Grand Forks range from 828 to 840 feet above mean sea level.

Grand Forks County is underlain by glacial drift, westward-sloping Paleozoic and Mesozoic sedimentary rock, and Precambrian igneous and metamorphic rock (Ref. 6). The glacial drift, which covers the bedrock at a maximum thickness of 455 feet, can be differentiated into five drift sheets each composed of till, lake clay, silt, sand, and gravel. Relief on the bedrock surface is much greater than relief on the glacial surface topography. The bedrock rises 600 feet from east to west on the Pembina Escarpment in western Grand Forks County compared to a rise in surface elevation of only 300 feet over the same area.

CLIMATE AND PRECIPITATION

Grand Forks has a dry, subhumid climate with large temperature variations, variable precipitation, and severe winters. Weather statistics from the U.S. Department of Agriculture indicate a low temperature of -43° F and a high temperature of 109° F for the period 1900 to 1940 (Ref. 6). The mean annual temperature for the same period was 39° F, with an average January temperature of 3.7° F and an average July temperature of 69° F. The average precipitation in Grand Forks County is 19.2 inches, three-fourths of which falls from May through September. The average annual snowfall in northeastern North Dakota is 35 inches (Ref. 7). The average annual water equivalent of the snowfall - the depth of water that would result from melting of the snow - is approximately 4 inches. Because prevailing winds are from the northwest, precipitation in Grand Forks usually occurs during local storms moving east through the area.

OTHER STUDIES AND PROJECTS

Several studies relating to urban drainage problems in Grand Forks have been completed recently, are in progress, or are in the planning stage. Each of these studies and projects is summarized below.

The Grand Forks-East Grand Forks Urban Water Resources Study, Plan of Study (Ref. 5) presents a detailed plan for studying flood control, water supply, and wastewater problems in Grand Forks, North Dakota, and East Grand Forks, Minnesota. The Grand Forks-East Grand Forks Urban Water Resources Study, Stage 2 Floodplain Management Appendix (Ref. 1), the Grand Forks-East Grand Forks Urban Water Resources Study, Stage 2 Wastewater Appendix (Ref. 8), and the Grand Forks-East Grand Forks Urban Water Resources Study, Stage 2 Water Supply Appendix (Ref. 9) were completed in accordance with the objectives of the Plan of Study.

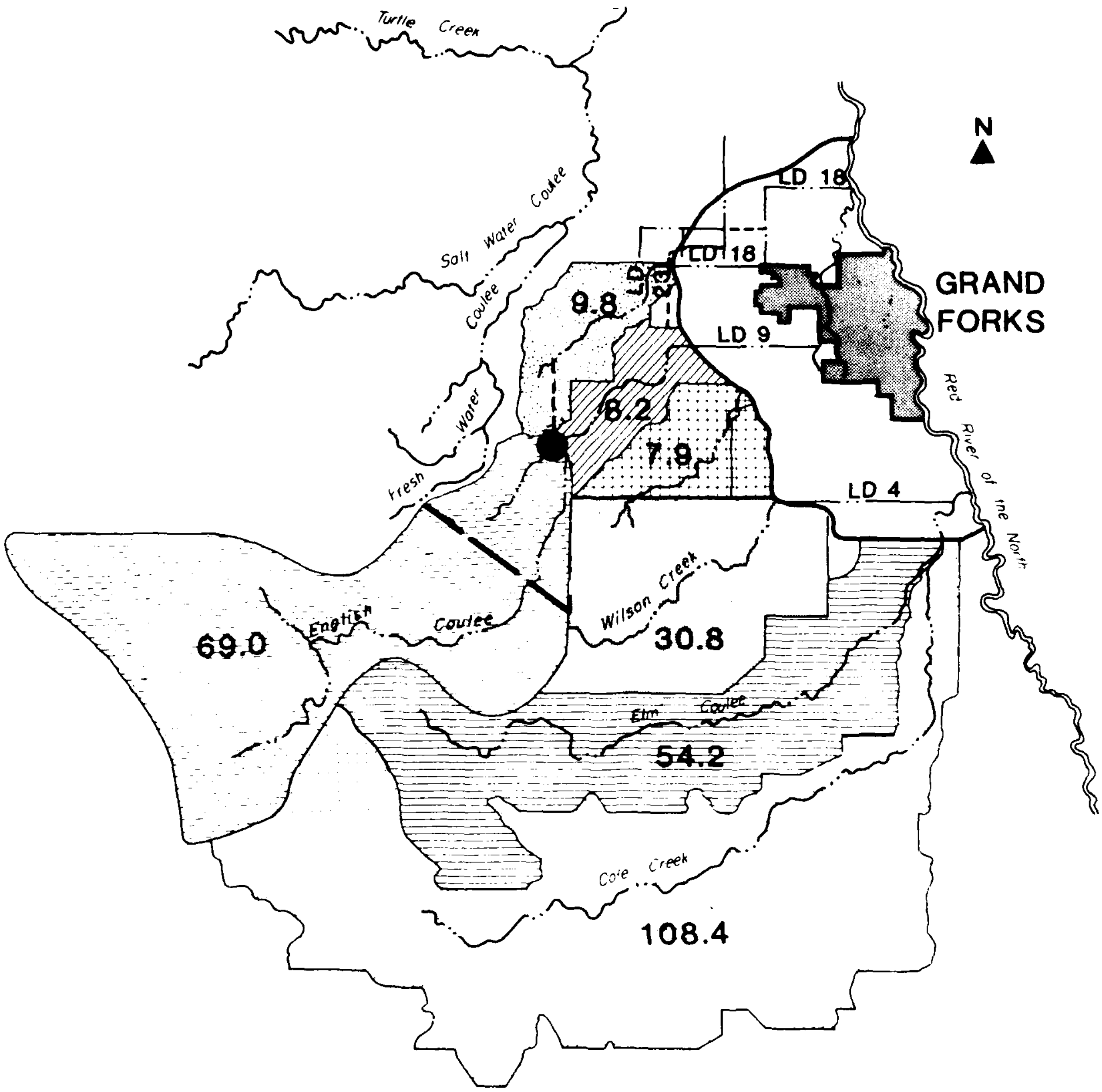
The Floodplain Management Appendix (Ref. 1) summarizes existing structural and nonstructural flood control programs in Grand Forks and outlines the city's basic flood damage reduction needs. It also presents preliminary alternatives for solving the city's urban drainage problems and recommends an overall drainage plan for the city. The Wastewater Appendix (Ref. 8) formulates a number of wastewater management alternatives for the Grand Forks-East Grand Forks area based on the area's existing facilities, the need to expand or upgrade those facilities, and the need to resolve problems caused by overflows from Grand Forks' combined sewers. The Water Supply Appendix (Ref. 9) reviews the sources, dependability, capacity, and quality of water supplies in the Grand Forks area, projects future water supply demands, identifies water supply and treatment needs, and identifies alternatives to meet those needs. Additional wastewater, water supply, and flood control studies are being conducted as part of stage 3 of the Grand Forks-East Grand Forks Urban Water Resources Study (Ref. 10), in accordance with the conclusions and recommendations of stage 2 studies.

The <u>Grand Forks Flood Insurance Study</u> (Ref. 11) summarizes the flood hazards in Grand Forks and presents floodplain boundaries and flood profiles for the Red River and English Coulee for the 100-year flood on the Red River. The flood insurance study identifies backwater from the Red River as the primary flood threat along the coulee within the city; however, the 1979 spring flood showed that flows in English Coulee caused by local runoff from areas tributary to the coulee pose an even greater flood threat.

The Soil Conservation Service (SCS), in cooperation with the city of Grand Forks, is considering several options to divert runoff from about 69 square miles tributary to English Coulee away from the city. The options include (Ref. 12):

1) Construction of an earth dam approximately 5 miles long crossing English Coulee in Section 12, T 150 N, R 52 W of Fairfield Township. The dam would create a pond with a surface area of 2.5-3.0 square miles for the 100-year flood. The inundated area would include about 0.25 square mile of farmland; the remainder would be pasture. The peak discharge from the dam into English Coulee would be 450 to 600 cfs (cubic feet per second) for the 100-year flood. The approximate location of the proposed dam is shown on figure 5.

2) Completion of the existing diversion structure in Section 30, T 151 N, R 51 W of Brenna Township. The area tributary to English Coulee between the dam and the diversion structure would be approximately 12 square miles. Water reaching the diversion structure would be conveyed via two separate channels to Legal Drain 18 where it would be recombined and routed to the Red River along a single path. One channel would convey runoff from the diversion structure north to the English Coulee floodway via a ditch to be completed in the near future, then northeast via the floodway to Legal Drain 23, then east approximately one-half mile via Legal Drain 18. The other channel would convey runoff from the diversion structure northeast via English Coulee to Legal Drain 9, then north via 1 mile of Legal Drain 9, then north via 2 miles of new ditch to Legal Drain 18. The runoff from the



108.4 Watershed Area, Square Miles

Study Boundaries
Watershed Divide
Diversion Structure
Proposed SCS Dam
New Ditch Required Under Proposed SCS Plan

FIGURE 5

TRIBUTARY WATERSHED MAP

AD-A110 363 CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT F/G 13/2
GRAND FORKS - EAST GRAND FORKS URBAN WATER RESOURCES STUDY. FLO--ETC(U)
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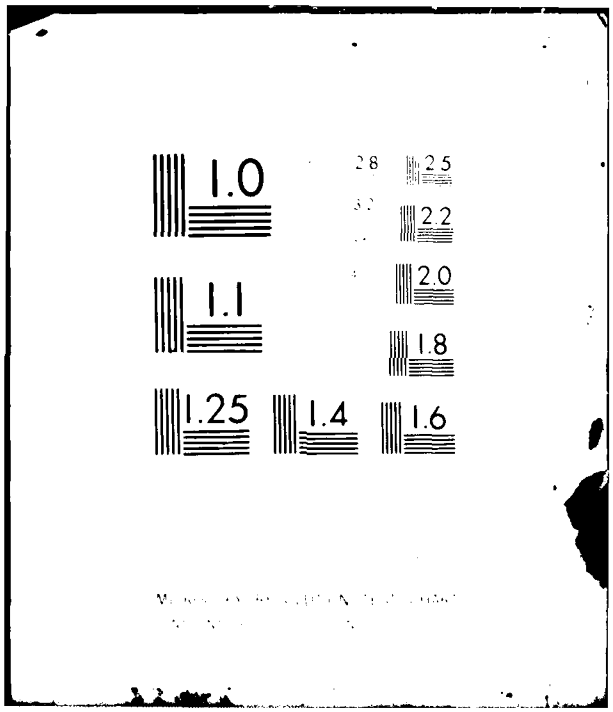

1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

two channels would be combined at Legal Drain 18 and would be routed northeast via a new ditch to the midpoint of the west section line of Section 35, T 152 N, R 51 W, then east via 1 mile of new ditch to Legal Drain 11, then north via 1 1/2 miles of Legal Drain 11, and finally east to the Red River via 1 mile of new ditch and 2 1/4 miles of Legal Drain 18. The locations of new ditches required under the SCS plan are shown on figure 5.

3) Development of sufficient channel capacity along the proposed diversion routes to carry local runoff and discharges routed through the diversion structure. This would involve construction of a bridge on U.S. Highway 2 with a capacity of approximately 800 cfs and improvement of the Legal Drain 18 crossings under Interstate 29 and the Burlington Northern railroad. Substantial channel excavation and other culvert improvements would also be required.

4) Construction of a barrier on the Grand Forks side of the diversion route from Legal Drain 18 south approximately 2 miles along the mid-section line of Sections 3 and 10 to Legal Drain 9.

5) Construction of a ditch and barrier from the proximity of English Coulee south 3 miles along the west section line of Sections 22, 27, and 34, T 151 N, R 51 W, then east about 1 1/3 miles along the south section line of Sections 34 and 35, T 151 N, R 51 W and connecting to Legal Drain 4 via an existing ditch.

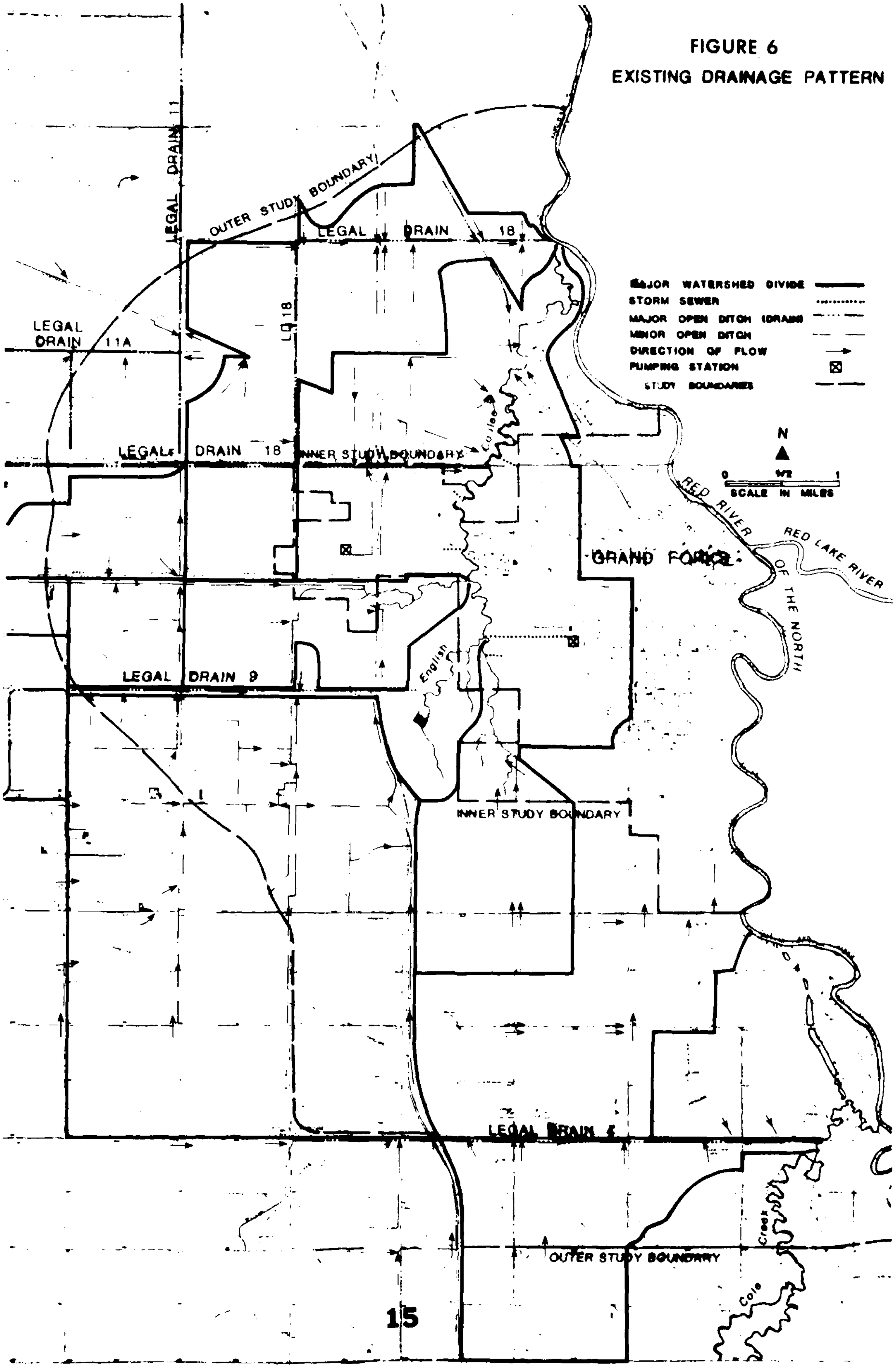
The implementation of these options would significantly reduce flooding along the English Coulee main channel in Grand Forks, but the legal aspects of interbasin water transfer and inundation of property must be thoroughly investigated.

HYDROLOGY

EXISTING DRAINAGE SYSTEM

Existing drainage patterns in the study area are shown on figure 6. The drainage system consists of natural creeks, artificial channels (shown on figure 2), and the city sewer system (shown on figure 7). Only storm sewers that discharge into English Coulee within the study area are shown on figure 6.

FIGURE 6
EXISTING DRAINAGE PATTERN



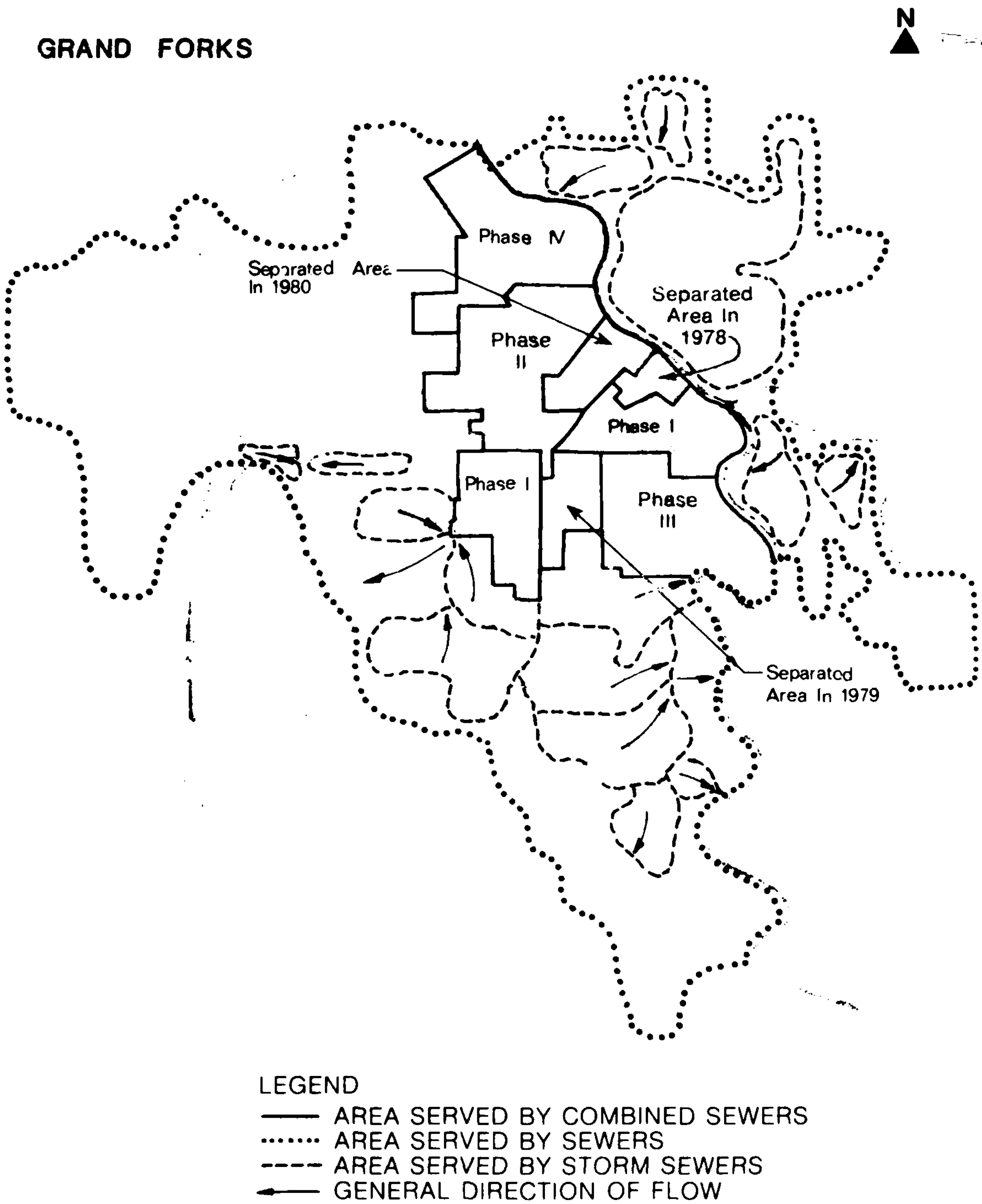


FIGURE 7

GRAND FORKS SEWER SYSTEM

Drainage areas outside but tributary to the study area are shown on the tributary watershed map (figure 5). The drainage area of the English Coulee tributary to the diversion structure was obtained from the SCS (Ref. 13); all other watershed boundaries shown in figure 5 were determined using U.S. Geological Survey topographic maps at a scale of 1 inch = 2,000 feet with 5-foot contour intervals.

The study area is drained primarily by two natural watercourses, English Coulee and Cole Creek. These streams are supplemented by artificial Legal Drains 4, 9, 11, 11A, 18, and 23 and the English Coulee floodway. The major components of the existing drainage system are discussed in more detail in the following paragraphs.

English Coulee Main Channel

The English Coulee main channel is the primary natural drainage feature within the study area. The stream flows north through the western portion of Grand Forks and discharges into the Red River just north of the city. The coulee has a drainage area of approximately 108 square miles at its mouth, including 22 square miles tributary to Legal Drain 9 and 69 square miles tributary to the diversion structure.

English Coulee is 7.6 miles long from the east end of Legal Drain 9 to the Red River; its average bed slope for this reach is 0.083 percent. The channel's bank-full cross-sectional area varies from 340 to 700 square feet with a weighted average of about 540 square feet. The capacity of the coulee is limited to approximately 1,000 cfs by obstructions and constrictions along its route. Obstructions include two check dams, one about 600 feet upstream of University Avenue and the other about 200 feet upstream of U.S. Highway 81. Major constrictions along the channel include the University Avenue, Burlington Northern railroad, and DeMers Avenue bridges. An analysis of the 1979 spring flood in Grand Forks indicated that the channel could handle a discharge of 1,000 cfs without causing serious flooding.

Legal Drain 9

Legal Drain 9 is an improved 4.6-mile section of English Coulee west of Grand Forks. The drainage area of Legal Drain 9 downstream of the diversion structure is approximately 22 square miles at the confluence with the English Coulee main channel. Approximately 6 square miles of the Legal Drain 9 drainage area are within the study boundaries. The drain has an average bed slope of 0.075 percent, an average bank-full cross-sectional area of 500 square feet, and a discharge capacity varying from 1,000 cfs at the outer study boundary to 1,800 cfs in the vicinity of Interstate 29.

Legal Drains 18, 23, 11, and 11A and the English Coulee Floodway

Legal Drains 18 and 23 are extensions of the English Coulee floodway. Legal Drain 23 connects the English Coulee floodway to Legal Drain 18. Legal Drain 18 extends from the north end of Legal Drain 23 east 3.0 miles along the south side of Highway 2, then turns north for 2.0 miles, and then runs east for 2.2 miles to the Red River of the North. Legal Drain 11 runs north from Highway 2 about 1.0 mile west of the north-south reach of Legal Drain 18 and discharges into a tributary of the Turtle River; the drain has a tributary area of about 24 square miles, a length of about 9.4 miles, an average slope of about 0.06 percent, and a flow capacity of about 190 cfs at the outlet. Legal Drain 11A is tributary to Legal Drain 11.

Legal Drain 18 has a tributary area of about 15 square miles downstream of the diversion structure, including 9.8 square miles tributary to the English Coulee floodway and Legal Drain 23. About 7.2 miles long with an average bed slope of 0.058 percent, Legal Drain 18 has an average bank-full cross-sectional area varying from 470 square feet just upstream of the outer study boundary to 920 square feet one-fourth mile upstream of the Red River; the discharge capacity varies from 1,000 to 3,000 cfs over this same reach. Culverts and bridges along the drain restrict discharges to 1,000 cfs at Interstate 29 and to 360 cfs at the culvert about 1 mile downstream of the drain's confluence with the English Coulee floodway.

Cole Creek

Cole Creek enters the Red River of the North about 2 miles south of the Grand Forks corporate limits. The Cole Creek watershed has an area of approximately 198 square miles, consisting of its direct drainage area, the Legal Drain 4 system, and the Wilson Creek and Elm Coulee watersheds. Elm Coulee, approximately 23 miles long, enters Cole Creek about 2 miles upstream of Cole Creek's confluence with the Red River of the North. Wilson Creek, about 10 miles long, discharges into the west end of Legal Drain 4.

Legal Drain 4

Legal Drain 4 runs east-west in the southern portion of the study area and discharges into Cole Creek near its outlet at the Red River of the North. The drain is approximately 4.7 miles long, and it has a predominantly rural drainage area of approximately 34 square miles, including the Wilson Creek watershed. Legal Drain 4 has an average bed slope of 0.056 percent, a bank-full cross-sectional area ranging from 120 square feet approximately 1 1/3 miles upstream of Interstate 29 to 165 square feet approximately three-quarter mile upstream of Cole Creek. The design discharge capacity varies from 390 cfs upstream of Interstate 29 to 430 cfs just downstream of Interstate 29 to 450 cfs at the outlet.

EXISTING DRAINAGE PROBLEMS

Grand Forks has three major drainage problems: (1) local flooding and temporary impoundment of runoff because of inadequate drainage facilities, (2) overflow of the city's combined wastewater and storm sewer system during heavy rainfalls, and (3) frequent flooding because of high flood stages on the Red River. The most severe conditions usually occur in the spring with a combined runoff of snowmelt and spring rain. Ice jams on the Red River and its tributary coulees, creeks, and ditches also tend to increase flood problems during the spring. The Grand Forks area drains naturally from southwest to northeast.

As shown on figure 5, large rural areas southwest of Grand Forks drain toward the city. Existing ditches (excluding legal drains) that transport runoff from these areas through the city are generally shallow and their slopes follow the natural surface topography. These facilities are, therefore, often inadequate for handling runoff that results from heavy rainfalls, and local sheet flow flooding often occurs during such storms. Problems caused by inadequate drainage facilities will increase as urban development continues in and around Grand Forks.

Sewer backups and the overflow of combined sewers cause basement flooding in Grand Forks during spring snowmelt and after heavy rainfalls. A four-phase project is under way to separate sanitary and storm sewer systems in the city. The areas covered by each phase of the project are shown on figure 7, along with areas where separation has been completed or is scheduled for completion in the near future. The stage 3 wastewater study, currently in progress, is evaluating the cost effectiveness of various solutions to the combined sewer overflow problem (Ref. 10). The study will satisfy Step 1 of the Environmental Protection Agency's Construction Grants Program, making the city eligible for Federal assistance on the sewer separation project.

Backwater from the Red River of the North causes serious flooding problems along the English Coulee main channel. Most of the downtown commercial area has experienced severe basement flooding and some first floor flooding during floods on the Red River, and local drainage has been seriously impaired by these flood flows. Because English Coulee is the primary drainage channel in the study area and because it has special aesthetic value, its maintenance and protection are major concerns.

The 1979 spring flood in Grand Forks clearly indicated that flood problems in the area are caused not only by high flood stages on the Red River but by inadequate drainage facilities within the study area. The SCS estimated that available runoff at the County Road 5 crossing at the entrance to Legal Drain 9 was nearly 2,000 cfs during the flood, yet the capacity of Legal Drain 9 downstream at the Interstate 29 crossing is only 1,000 cfs. As shown by aerial photographs of the flood (Ref. 14), water backed up and overtopped Interstate 29, creating a substantial flood hazard in that area.

Aerial photos also indicate that substantial flooding occurred at the Burlington Northern railroad crossing on the English Coulee main channel (Ref. 14); a 1-mile reach of DeMers Avenue was completely inundated by these floodwaters. This local flooding occurred before the peak flood stage was reached on the Red River, and the flood elevations were higher than the 100-year flood elevations estimated for English Coulee in the Grand Forks Flood Insurance Study (Ref. 11).

High-water marks along English Coulee obtained by the Grand Forks Engineering Department during the 1979 spring flood indicate that a head loss of 1.23 feet occurred across the University Avenue Bridge during the flood (Ref. 15). This information, along with other hydraulic data and aerial photographs, indicates that the University Avenue Bridge passed a discharge of approximately 1,150 cfs with about one-half foot of water flowing over the road. High-water marks at the Burlington Northern railroad crossing show a head loss of 2.9 feet across the culvert during the flood; this high head loss indicates the severity of the constriction. Other obstructions along English Coulee, including small check dams built for aesthetic purposes, similarly reduce the channel capacity and increase water surface elevations during flooding.

EXISTING FLOOD CONTROL MEASURES

The only permanent flood control project in Grand Forks is a 5,160-foot earthen levee and a 770-foot reinforced concrete floodwall along the Red River in the Lincoln Park area. This flood barrier protects residences and businesses in the area from a 36-year frequency flood on the Red River (Ref. 1). Emergency levees in place in Grand Forks consist of the 1,500-foot Central Park levee, constructed during the 1971 flood emergency, and the 3,450-foot Riverside Park levee, constructed in 1971 and modified in 1975. The Central Park and Riverside Park levees protect from a 30-year flood on the Red River (Ref. 1). As indicated previously, a sewer separation project is under way in Grand Forks to ease interior drainage problems caused by backups in the city's combined storm and sanitary sewer system (figure 7).

PLAN FORMULATION

OBJECTIVES

A master drainage plan should be adopted and enforced in Grand Forks to minimize drainage problems and flooding within the city. The plan should incorporate current design standards and it should meet the following objectives of stormwater management:

- Minimize existing and future impacts of storm drainage.
- Provide a drainage plan with maximum net economic efficiency.
- Enhance and preserve the quality of the environment.
- Stimulate an orderly and systematic water and related land use plan within the study area.
- Develop a staged drainage plan consistent with the growth objectives of the study area and adjacent areas.

DESIGN CRITERIA

Two master drainage options have been developed for Grand Forks to meet the above objectives and the particular needs of the city. The two options, presented in the section beginning on page 26, are based on the following design criteria:

1. Design runoff rates and volumes are based on land use for the year 2030 (table 1).
2. Lateral storm sewers were sized to convey runoff from a rainfall with an average return period of 10 years (10 percent probability of occurrence in any given year) with no flooding in the streets.

3. All storage areas, major trunk sewers, culverts, and legal drains were sized to convey runoff from a rainfall with an average return period of 100 years (1 percent probability of occurrence in any given year).

4. It was assumed that natural drainage patterns in undeveloped areas outside but tributary to the study area would not be altered by future development.

5. It was assumed that some combination of the SCS flood control options discussed earlier would be implemented to limit discharges entering the study area to the capacities of existing channels, culverts, and bridges at the outer study boundary. On the basis of this assumption:

   a. A maximum of 1,000 cfs would be routed through the English Coulee main channel (via Legal Drain 9) for the 100-year flood; 1,000 cfs is the discharge capacity of Legal Drain 9 at the outer study boundary.

   b. A maximum of 360 cfs would be routed through Legal Drain 18 for the 100-year flood; the capacity of the English Coulee floodway upstream of its confluence with Legal Drain 18 is approximately 600 cfs, but the capacity of the culvert on Legal Drain 18 about 1 mile downstream of the confluence is only 360 cfs.

   c. A maximum of 430 cfs would be routed through Legal Drain 4 for the 100-year flood; the discharge capacity of the bridge under Interstate 29 is limited to 430 cfs under existing conditions because of channel bank elevations immediately upstream of the bridge.

6. It was assumed that the 100-year discharge entering the Legal Drain 9 system from the south at the outer study boundary (area D7, figure 8) would be limited to 100 cfs. Because of local ground slopes and tailwater conditions in Legal Drain 9, discharges in excess of 100 cfs will cause flooding in area D5 (figure 8).

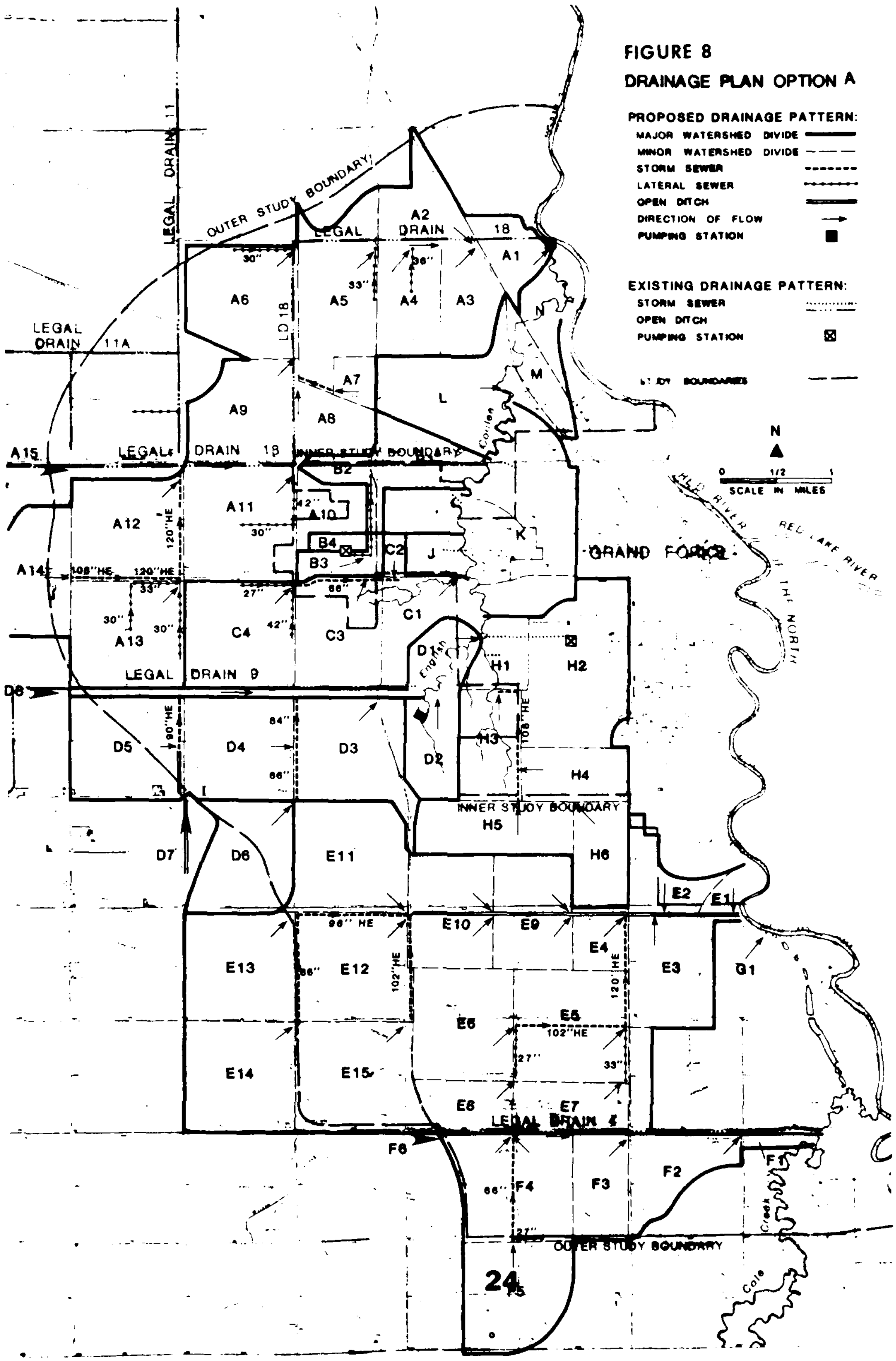


FIGURE 8
DRAINAGE PLAN OPTION A

METHODOLOGY

Major watershed divides and subwatershed divides for areas within and tributary to the study area were determined using aerial photos, drainage maps and sewer plans obtained from local and State agencies, and 5-foot contour interval topographic maps obtained from the U.S. Geological Survey. A field survey was conducted to define subwatershed boundaries in areas where available data were insufficient. The use of more detailed topographic maps could effect minor changes in the watershed boundaries, but such changes would not significantly affect the proposed drainage options.

Hydraulic data for the English Coulee main channel, the English Coulee floodway, and Legal Drains 4, 9, 18, 11, and 11A were obtained from plans, profiles, and cross sections provided by the SCS. This information was supplemented by field survey data. All information used in the study was collected previously and summarized in the Draft Report, Grand Forks Urban Drainage Plan, Part 1, Stage 3 (Ref. 16).

Runoff discharges and volumes for waterways within the study area were determined using the Barr Hydrograph Method, a synthetic hydrograph method developed by Barr Engineering Company for urban drainage analyses. Discharges determined using the Barr Method were checked using the Rational Method of runoff calculation. (See Attachment 1 for a discussion of the Barr and Rational Methods.) Runoff hydrographs for watersheds upstream of the outer study boundary were determined using the SCS hydrologic model TR-20 in conjunction with the SCS dimensionless Type I rainfall distribution hyetograph. Runoff resulting from both rainfall and snowmelt and a combination of the two was considered in determining the critical storms for waterways affecting the study area.

URBAN DRAINAGE MASTER PLAN

INTRODUCTION

The drainage systems proposed under each of the two plans for minimizing drainage problems and flooding in Grand Forks - Options A and B - are shown in figures 8 and 9, respectively. The options were developed in accordance with the design criteria presented in the previous section. The primary difference between the two options is that Option B provides for the development of stormwater ponding areas and Option A does not. Under Option B, peak runoffs in the study area will not increase beyond existing conditions as development takes place.

Options A and B maximize the use of existing drainage systems (figure 4) and minimize the use of open ditches. To divert runoff away from the English Coulee main channel, both options incorporate a subwatershed drainage pattern different from that now existing; this drainage pattern will be referred to as the "proposed drainage pattern." By reducing flooding risks in homes, businesses, roads, and undeveloped areas, Options A and B increase the amount of usable land and enhance the overall quality of life and environment in the Grand Forks area.

Runoff discharges and volumes corresponding to subwatersheds within the study area under future land use conditions are summarized for both options in table 2. Discharges and volumes of runoff for the proposed drainage pattern with existing land use conditions are presented for comparison. Because runoff volumes and discharges can be computed to within 10-percent accuracy using the Barr Hydrograph Method, volumes and discharges in table 2 have been rounded to the nearest 1 acre-foot and the nearest 5 cfs, respectively.

DRAINAGE PLAN OPTION A

Option A, shown in figure 8 assumes no storage of runoff within the study area. Instead, the option is designed to convey all runoff from fully developed urban areas directly into storm sewers and ditches and finally into the Red River.

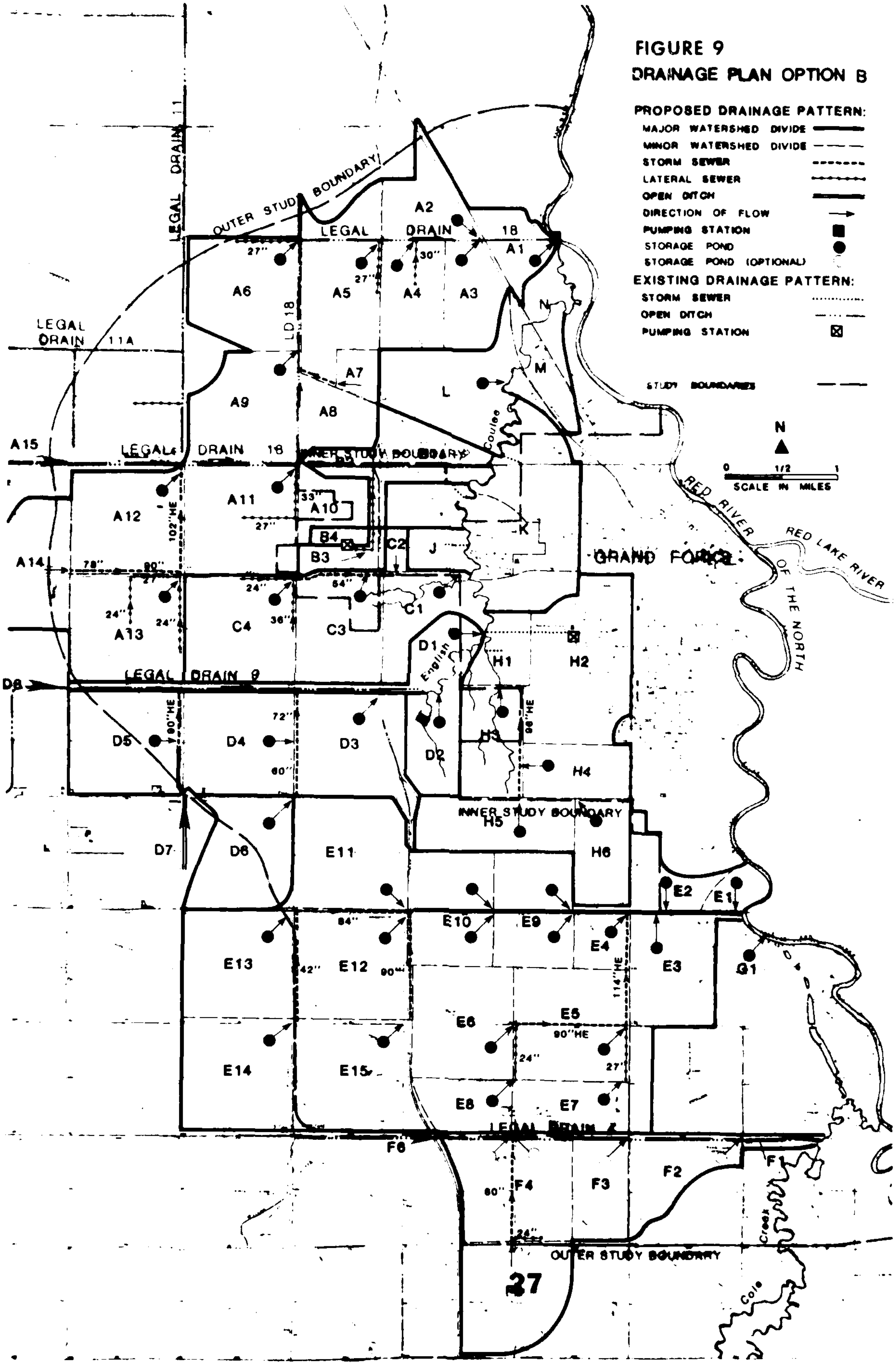


FIGURE 9
DRAINAGE PLAN OPTION B
PROPOSED DRAINAGE PATTERN:
MAJOR WATERSHED DIVIDE
MINOR WATERSHED DIVIDE
STORM SEWER
LATERAL SEWER
OPEN DITCH
DIRECTION OF FLOW
PUMPING STATION
STORAGE POND
STORAGE POND (OPTIONAL)
EXISTING DRAINAGE PATTERN:
STORM SEWER
OPEN DITCH
PUMPING STATION
STUDY BOUNDARIES
N
0 1/2 1
SCALE IN MILES
LEGAL DRAIN 11
LEGAL DRAIN 11A
OUTER STUDY BOUNDARY
LEGAL DRAIN 18
LD 18
LEGAL DRAIN 9
LEGAL DRAIN 7
INNER STUDY BOUNDARY
GRAND FORKS
RED RIVER OF THE NORTH
RED LAKE RIVER
Coulee
English
Cole Creek
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15
B3 B4 C1 C2 C3 C4
D1 D2 D3 D4 D5 D6 D7 D8
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15
F1 F2 F3 F4 F6 G1
H1 H2 H3 H4 H5 H6
J K L M N
27

Table 2 - Comparion of discharges and corresponding runoff volumes, proposed drainage pattern, 100-year frequency storm

	EXISTING LAND USE (1978)		FUTURE LAND USE (2030)				
			OPTION A		OPTION B		
Area Name*	Qmax (cfs)	Runoff Volume (A-F)	Qmax (cfs)	Runoff Volume (A-F)	Qmax (cfs)	Runoff Volume (A-F)	Storage Volume (A-F)
A1	140	20	165	24	140	24	4
A2	200	36	265	51	200	51	15
A3	185	34	230	43	185	43	9
A4	145	26	180	33	145	33	7
A5	165	28	195	46	165	46	18
A6	230	52	265	60	230	60	8
A7	40	9	45	11	40	11	2
A8	85	22	145	37	85	37	15
A9	265	50	310	59	265	59	9
A10	80	21	105	27	80	27	6
A11	165	47	195	57	165	57	10
A12	210	43	250	53	210	53	10
A13	175	47	210	57	175	57	10
A14	125	37	155	46	125	46	9
B1	280	46	320	51	280	51	5
B2	20	5	20	8	20	8	3
B3	40	11	65	18	40	18	7
B4	30	5	40	6	30	6	1
C1	170	26	190	29	170	29	3
C2	20	4	40	8	20	8	4
C3	205	44	345	76	205	76	32
C4	135	40	160	49	135	49	9
D1	115	18	130	21	115	21	3
D2	190	27	315	47	190	47	20
D3	185	46	220	56	185	56	10
D4	165	45	195	54	165	54	9
D5	155	42	180	50	155	50	8
D6	115	32	140	39	115	39	7

Table 2 - Comparison of discharges and corresponding runoff volumes, proposed drainage pattern, 100-year frequency storm (cont)

Area Name*	EXISTING LAND USE (1978) Qmax (cfs)	EXISTING LAND USE (1978) Runoff Volume (A-F)	FUTURE LAND USE (2030) OPTION A Qmax (cfs)	OPTION A Runoff Volume (A-F)	OPTION B Qmax (cfs)	OPTION B Runoff Volume (A-F)	OPTION B Storage Volume (A-F)
E1	60	8	65	10	60	10	2
E2	75	17	90	20	75	20	3
E3	140	40	165	48	140	48	8
E4	40	11	50	13	40	13	2
E5	115	39	140	47	115	47	8
E6	115	38	140	46	115	46	8
E7	40	13	45	16	40	16	3
E8	40	12	45	14	40	14	2
E9	90	28	115	36	90	36	8
E10	85	28	110	35	85	35	7
E11	150	45	180	54	150	54	9
E12	135	41	165	50	135	50	9
E13	85	30	100	37	85	37	7
E14	70	27	90	33	70	33	6
E15	120	37	145	45	120	45	8
F1	50	5	60	6	50	6	1
F2	75	22	90	26	75	26	4
F3	100	26	125	32	100	32	6
F4	135	39	160	47	135	47	8
F5	95	30	115	37	95	37	7
G1	1,245	149	1,340	167	1,245	167	18
H1	145	15	180	19	145	19	4
H2	440	93	450	95	440	95	2
H3	120	34	160	46	120	46	12
H4	-	-	-	-	-	-	-
H5	80	26	105	35	80	35	9
H6	60	20	90	30	60	30	10

Table 2 - Comparison of discharges and corresponding runoff volumes, proposed drainage pattern, 100-year frequency storm (cont)

Area Name*	EXISTING LAND USE (1978)		FUTURE LAND USE (2030)				
			OPTION A		OPTION B		
	Qmax (cfs)	Runoff Volume (A-F)	Qmax (cfs)	Runoff Volume (A-F)	Qmax (cfs)	Runoff Volume (A-F)	Storage Volume (A-F)
I	170	28	190	32	170	32	4
J	190	25	195	26	190	26	1
K	570	108	635	120	570	120	12
L	530	66	855	92	530	92	26
M	105	26	110	29	105	29	3
N	120	19	135	21	120	21	2

*Areas labeled on figures 8 and 9.

Option A requires alteration of existing drainage patterns to provide relief in two major problem areas - the English Coulee main channel and the area south of 32nd Avenue South between U.S. Highway 81 and the Red River. Specifically, this option proposes construction of an open ditch along 47th Avenue South from Interstate 29 to the Red River of the North to divert water away from the English Coulee. The 47th Avenue ditch would be about 3¼ miles long with a discharge capacity of 570 cfs at the upstream end (Interstate 29) and a capacity of 1,115 cfs at the outlet (Red River) for this option. Assuming no freeboard, a trapezoidal channel with a cross-sectional area varying from 170 square feet at Interstate 29 to 290 square feet at the outlet, side slopes of 2 horizontal to 1 vertical, and an average bed slope of 0.075 percent will pass these design discharges. Three miles of major trunk sewers would feed into the western end of the ditch at Interstate 29. Preliminary sizes for these trunk sewers are shown on figure 8. Option A also requires the improvement of existing culverts, bridges, and channels within the study area, particularly along the English Coulee main channel, to handle existing flood problems.

As shown in figure 8, a pumping station and closure structure are required at the outlet of Legal Drain 18 and English Coulee. The closure structure would be closed whenever backwater from the Red River of the North alone or in combination with runoff from the English Coulee watershed threatened properties bordering Legal Drain 18 and English Coulee. The pumping station would prevent discharges in the legal drain and coulee from ponding to damaging levels. Conditions requiring use of the pumping station and closure structure are most likely to occur during spring snowmelt. River stages resulting from summer rainfalls are generally low enough that the closure structure could be left open for gravity discharge from Legal Drain 18 and English Coulee.

The stage 3 flood control study is evaluating an alternative that consists of a closure structure and pumping station near the mouth of English Coulee to prevent backwater flooding from the Red River (Ref. 10). This scheme could be modified to control the outlet of Legal Drain 18 as well. However, the economic feasibility of the basic plan has not yet been ascertained.

On the basis of a preliminary analysis, a pumping station with a capacity of about 2,000 cfs under a hydraulic head of approximately 5 feet would pass discharges for Option A from English Coulee and Legal Drain 18 into the Red River while preventing backwater from the river from entering these channels. Five acre-feet of reservoir capacity should be provided upstream of the pumping station to allow staging of pumps.

DRAINAGE PLAN OPTION B

Option B, shown in figure 9, differs from Option A primarily in that it provides for storage areas to reduce peak discharges. Peak discharges with the proposed drainage pattern of Option B are the same as those that would occur with existing land use conditions; runoff volumes are the same as those for Option A with projected 2030 land use conditions. Storage volumes required under Option B represent changes in runoff resulting from future development.

A conceptual plan of ponding sites for stormwater storage is shown on figure 9. The actual size, shape, and location of ponds (or inundation areas) should be determined by detailed case-by-case analysis if Option B is selected for implementation. Individual storage areas may be combined as long as the combined areas have volumetric capacities equal to the sum of the individual capacities of the replaced areas. Storage may be provided in several ways, depending upon the specific needs of each planned unit development within the study area. New pond and park areas can be developed for recreational and aesthetic use where natural ponding sites are available, or existing park areas can be landscaped to provide the required storage volumes. If developable land is scarce or expensive, depressed parking lots, flat building roofs, and roadside ditches with controlled outlets can be used to retain stormwater runoff.

Well-designed stormwater ponding and detention areas are usually cost effective for municipalities, since the costs of developing storage areas can be deferred to future developers. Developers, in turn, have lower costs (and thus lower assessments) because of smaller pipes required for trunk and lateral storm sewers. A more detailed discussion of stormwater storage practices is presented in Attachments 2 and 3.

As with Option A, Option B requires construction of the 47th Avenue ditch to divert water south of 32d Avenue South away from the English Coulee. The required capacity of the ditch would be 470 cfs at the upstream end (Interstate 29) and 920 cfs at the outlet (Red River) for this option. On the basis of the preliminary design for Option B and assuming no freeboard, a trapezoidal channel with a cross-sectional area varying from 145 square feet at Interstate 29 to 250 square feet at the outlet, side slopes of 2 horizontal to 1 vertical, and a bottom slope of 0.075 percent will pass these design discharges.

As with Option A, a closure structure and a pumping station are required at the outlet of Legal Drain 18 and English Coulee under Option B. The structure would be closed whenever backwater from the Red River, alone or in combination with runoff from the English Coulee watershed, threatened properties bordering Legal Drain 18 and English Coulee. The pumping station would prevent discharges in the legal drain and coulee from ponding to damaging levels. Conditions requiring use of the pumping station and closure structure are most likely to occur during spring snowmelt. River stages resulting from summer rainfalls are generally low enough that the closure structure could be left open for gravity discharge from Legal Drain 18 and English Coulee. The pumping station should have a capacity of about 1,500 cfs with a hydraulic head of approximately 5 feet under Option B. Five acre-feet of reservoir capacity should be provided upstream of the station to allow staging of pumps.

As mentioned previously, the stage 3 flood control study is evaluating an alternative that consists of a closure structure and pumping station near the mouth of English Coulee to prevent backwater flooding from the Red River (Ref. 10). This scheme could be modified to control the outlet of Legal Drain 18 as well. The economic feasibility of the alternative has not yet been ascertained, however.

COMPARISON OF ALTERNATIVES

ECONOMIC IMPACTS

Preliminary cost estimates for Options A and B are shown in table 3. As indicated, Option B is more cost effective. The cost estimates must be updated upon completion of the final design for the selected drainage plan. The unit costs presented for the open ditch have been overestimated by about 10 percent to allow for oversizing of the channel to reduce maintenance costs.

The estimates in table 3 do not include administrative costs of the city of Grand Forks or costs associated with the development of ponding sites under Option B. The costs of developing ponding sites can be deferred to future land developers.

ENVIRONMENTAL IMPACTS

The primary environmental impacts associated with constructing and operating an urban drainage system are problems of soil erosion, siltation, water quality degradation, and the disturbance of natural resources and ecological systems. Implementation of either option would require erosion control measures during construction to prevent damage to cut or fill slopes and natural drainageways in potential problem areas. Erosion control would also be required after construction to minimize scouring in natural waterways and reduce siltation in pipes. Sodding should provide adequate surface protection in most cases.

Both options would minimize the potential for environmental impacts associated with the construction of new drainage facilities by providing for maximum use of existing facilities. The 47th Avenue ditch, for example, could probably be built by improving existing ditches along 47th Avenue. In addition, new lateral sewers and major trunk sewers required under the proposed plans would generally affect only undeveloped areas where construction will not have a negative impact on existing developments. The major differences in construction required for

Table 3 - Preliminary cost estimates*

OPTION A

ITEM	Quantity	Unit	Unit Cost	Item Cost	Total Cost	Annual Cost
Open Ditch	3¼	mi	221	718		
Open Ditch Outlet	1	ea	12	12		
Total Cost of 47th Avenue Open Ditch					730	
RCP 120" HE	2½	mi	1,963	4,908		
RCP 108" HE	1½	mi	1,752	2,628		
RCP 102" HE	2	mi	1,620	3,240		
RCP 96" HE	1	mi	1,488	1,488		
RCP 90" HE	½	mi	1,382	691		
RCP 84"	½	mi	1,039	520		
RCP 66"	3	mi	770	2,888		
RCP 42"	1	mi	495	495		
RCP 36"	½	mi	402	201		
RCP 33"	1½	mi	339	508		
RCP 30"	2	mi	270	540		
RCP 27"	1¼	mi	207	259		
Total Cost of Storm Sewers (18 miles)					18,366	
Pump Station	2,000	cfs	2.6	5,200		
Pond	5	AF	4.0	20		
Total Cost of Special Outlet Structure					5,220	
Contingencies					6,890	
Engineering					3,445	
TOTAL FIRST COST OF OPTION A					34,651	
Annual Capital Recovery Cost at 6 %, 50 years						2,471
Annual Operation & Maintenance						
Open Ditch	3¼	mi	0.6	2		
S. Sewers	18	mi	0.4	7		
Sp. Outlet	1	ea	20	20		
Total Annual Operation & Maintenance						29
AVERAGE ANNUAL COST						2,500

*Cost Unit is $1,000

Table 3 - Preliminary cost estimates* (cont)

OPTION B

ITEM	Quantity	Unit	Unit Cost	Item Cost	Total Cost	Annual Cost
Open Ditch	3¼	mi	196	637		
Open Ditch Outlet	1	ea	10	10		
Total Cost of 47th Avenue Open Ditch					647	
RCP 114" HE	1	mi	1,858	1,858		
RCP 102" HE	1	mi	1,620	1,620		
RCP 96" HE	1	mi	1,488	1,488		
RCP 90" HE	1½	mi	1,382	2,073		
RCP 84" HE	1	mi	1,277	1,277		
RCP 90"	1½	mi	1,145	1,718		
RCP 78"	½	mi	949	474		
RCP 72"	½	mi	860	430		
RCP 60"	½	mi	680	340		
RCP 54"	1¼	mi	585	731		
RCP 42"	1	mi	495	495		
RCP 36"	½	mi	402	201		
RCP 33"	½	mi	339	170		
RCP 30"	½	mi	270	135		
RCP 27"	2½	mi	207	466		
RCP 24"	2¼	mi	144	308		
Total Cost of Storm Sewer					13,784	
Pump Station	1,500	cfs	2.6	3,900		
Pond	4	AF	4.0	16		
Total Cost of Special Outlet Structure					3,916	
Contingencies	20%				5,186	
Engineering	10%				2,593	
TOTAL FIRST COST OF OPTION B					26,126	
Annual Capital Recovery Cost at 6 %, 50 years						1,863
Annual Operation & Maintenance						
Open Ditch	3¼	mi	0.6	2		
S. Sewer	18	mi	0.4	7		
Sp. Outlet	1	ea	15	15		
Total Annual Operation & Maintenance						24
AVERAGE ANNUAL COST						1,887

*Cost unit is $1,000

Options A and B would be that larger pipes and ditches are required under Option A, ponding areas must be developed only under Option B, and a larger pumping facility would be required at the outlets of English Coulee and Legal Drain 18 under Option A.

Contaminants such as fertilizers tend to collect and concentrate in storm runoff, contributing to water quality problems in storage ponds downstream of storm sewer outlets. Water quality concerns are greater under Option B, because Option B would use storage basins to reduce the volume of runoff passing through the study area. The siting of ponds under Option B should be done so as to enhance ecological systems within the study area. There are no natural wetland habitats within affected parts of the study area.

SOCIAL AND CULTURAL IMPACTS

Both options would enhance the social and cultural environment in the study area by providing for the control of storm runoff and the reduction of existing flood problems. Option B, however, would increase recreational opportunities (fishing, canoeing, picnicking, golfing, and hiking) because of its requirement for ponds and inundation areas in parks and open spaces. Recreational facilities provided under Option B could reduce the future shortage of recreational facilities projected for the Grand Forks area in the Grand Forks-East Grand Forks Leisure Time Analysis (Ref. 17). Option B has another advantage in that it would allow the city flexibility in land use zoning regulations and implementation schedules. Because peak runoffs from subwatersheds are fixed under Option B, zoning ordinances could be altered as desired as long as storage areas and outlet structures are provided to control drainage from developments.

INSTITUTIONAL IMPACTS

Adoption of a drainage master plan in Grand Forks would require institutional change and coordination to ensure successful implementation of the plan. To guide future development and drainage construction within its jurisdiction, the city may adopt a drainage ordinance similar to the sample ordinance presented in Attachment 4. Such an ordinance should be carefully

designed to meet the particular flood control needs of the city. Coordination would also be required between various State and county agencies regarding the city's interests in watersheds outside the study area. The agreements should govern drainage changes that could affect runoff volumes, peak discharges, and discharge hydrographs within the study area. Specific agreements should also be drafted to control the quality of water entering Grand Forks.

According to the Grand Forks City Attorney, neither the city, the Grand Forks Drainage Board, nor the Grand Forks County Water Management and Control Board presently has the legal authority to enforce a drainage plan in the Grand Forks study area. One possible way for the city to obtain this authority would be to form a watershed district with the responsibility and legal authority to implement drainage schemes and assess costs to landowners, developers, and municipalities in proportion to their contribution to drainage problems and their potential benefit from drainage solutions. Watershed districts traditionally have jurisdiction over whole watersheds. The Grand Forks County Water Management and Control Board could take on the responsibilities and power of a watershed district if the formation of a separate body is not feasible or desirable.

The development of ponds or inundation areas under Option B would require coordination between the Grand Forks Park Board, developers, planners, and engineers to ensure full attainment of the environmental, social, and economic benefits of the option. The city of Grand Forks would have to provide sufficient staff and funds to maintain the drainage systems proposed under both options.

RECOMMENDED DRAINAGE PLAN

It is recommended that the city of Grand Forks implement Option B using storage areas, ditches, main trunk sewers, and lateral sewers as illustrated in figure 9. Option B requires that storage areas be developed in subwatershed areas as future development occurs to limit runoff discharges to peaks that occur under existing land use conditions. This option requires smaller pipes than would be required to pass discharges under future land use conditions with no ponding (Option A, figure 8). As shown in table 3, these size reductions yield cost savings to the city; the costs of storage

development under Option B can be deferred to developers at the time of future land development. Ponding areas provided under Option B are potential aesthetic and recreational resources for future land users.

Implementation of a drainage master plan in Grand Forks will require consideration of restrictions on existing and proposed drainage systems. Specifically, the inflow hydrographs to Legal Drains 18, 9, and 4 must be controlled on the basis of the capacities of channels, culverts, and bridges within the study area. The inflow hydrograph to Legal Drain 18 must be limited to a peak discharge of 360 cfs for the 100-year frequency event since the capacity of the culvert on Legal Drain 18 approximately 1 mile downstream of the confluence with the English Coulee floodway is 360 cfs. The inflow hydrograph entering Legal Drain 9 at the outer study boundary must be limited to a peak discharge of 1,000 cfs for the 100-year frequency event, and the runoff entering the Legal Drain 9 system from the south at the outer study boundary must be limited to a discharge of 100 cfs for the same event. Channel bank elevations limit the discharge in Legal Drain 4 under the Interstate 29 bridge to 430 cfs for the 100-year flood, so any alteration of drainage patterns upstream of Interstate 29 must be controlled to minimize peak discharges in the channel. Water will overflow the channel banks onto the open fields adjacent to Legal Drain 4 at discharges greater than 430 cfs.

Because Option B is based on discharges corresponding to existing land use conditions, it can be implemented for flood mitigation as funds become available. The primary objective of the plan - to decrease flood levels on English Coulee - can be substantially fulfilled early in the implementation phase by constructing the 47th Avenue ditch and designing and constructing the pumping station and closure structure at the outlets of Legal Drain 18 and the English Coulee main channel. The pumping station and closure structure could initially be constructed to control flow only at the mouth of English Coulee, as suggested by the stage 3 flood control study (Ref. 10). The facilities could be expanded to include the mouth of Legal Drain 18 when the Legal Drain 18 floodplain is sufficiently developed to warrant increased flood protection. Existing ditches should be graded in the initial

stages of implementation to establish the drainage patterns illustrated in figure 9. Main trunk sewers and laterals proposed for Option B can be built as land development occurs and the presence of open ditches within the study area becomes undesirable.

If the SCS plan to divert runoff from Legal Drain 9 is implemented (see page 11), the selected drainage option (A or B) should be carefully analyzed to determine the impact of altered drainage patterns on that option. The area tributary to Legal Drain 9 and outside the study boundary would be reduced from 85 square miles at present (69 square miles tributary to the diversion structure and watershed areas D7 and D8, figure 8) to about 8 square miles under the SCS plan (area D7). This 8-square-mile watershed would generate a peak 100-year discharge of about 900 cfs.

Under present conditions, the discharge from area D7 at the outer study boundary is limited to 100 cfs under Options A and B because of local ground slopes and tail-water conditions in Legal Drain 9. Tail-water elevations in Legal Drain 9 would be reduced significantly under the SCS plan, however, since discharges from English Coulee and area D8 would be conveyed away from the drain. Implementation of the SCS plan could, therefore, eliminate the 100-cfs constraint on the discharge from area D7, and the full 900 cfs could be discharged into Legal Drain 9.

Because it was assumed for the present study that the peak 100-year discharge entering Legal Drain 9 at the outer study boundary would be 1,000 cfs, flow in Legal Drain 9 would be reduced by 100 cfs under the SCS plan. This reduction would make the proposed Options A and B more efficient, but such a small reduction would probably not justify major changes in the options. Before implementation of the selected drainage plan, it may be desirable to determine the feasibility and cost effectiveness of retaining the 100-cfs limit on discharges from area D7 to allow modification or elimination of the 47th Avenue ditch; other more economical alternatives might also be developed on the basis of the SCS plan.

Because peak discharges would enter Legal Drain 9 much sooner under the SCS plan than under existing conditions, peak flows in English Coulee would probably reach the Red River long before peak flood stages were reached on the river. Backwater problems along the coulee would be reduced by the SCS plan, and a much smaller pumping station would be required at the coulee outlet. However, because flows diverted from English Coulee would be routed through Legal Drain 18, the larger outlet facility might still be required. The final SCS plan should be analyzed to determine its effect on the timing of peak discharges in Legal Drain 18.

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ATTACHMENTS

ATTACHMENT 1: TECHNICAL APPENDIX

ATTACHMENT 2: STORMWATER STORAGE PRACTICES

ATTACHMENT 3: MANAGEMENT OF RETENTION BASIN WATER QUALITY

ATTACHMENT 4: SAMPLE DRAINAGE ORDINANCE

ATTACHMENT 1: TECHNICAL APPENDIX

PRINCIPLES OF URBAN DRAINAGE

The two primary considerations in the design of urban drainage systems are the rate and volume of storm runoff available for transport through a system. The rate of runoff is the determining factor in the design of storm sewers, and runoff volumes are critical in the design of storage basins. For a given period of time, runoff rates and volumes depend directly upon the intensity of rainfall and physical characteristics of a watershed such as the extent and location of impervious areas and depression storage areas, the infiltration capacity of topsoil and underlying strata, the extent and type of vegetative cover, topography, basin shape, and overland flow distances.

Rainfall intensity for a storm can be expressed graphically using the hyetograph, a plot of precipitation intensity versus time. The volume of rainfall and the rate at which it becomes available for surface runoff are determined by subtracting from the hyetograph water which infiltrates into the soil, is held in depression storage or is intercepted by vegetation at the initial time of precipitation. Figure A-1 shows a typical hyetograph for a 1-hour rainfall with an average return period of 5 years. Infiltration, depression storage, and interception losses typical of a residential, turfed area (expressed as a function of time) are superimposed on this hyetograph. As shown, the rate at which precipitation becomes available for surface runoff at a given time is equal to the ordinate of the hyetograph minus the ordinate of the accumulated losses. Similarly, the volume of precipitation available for runoff is equal to the difference between the area under the hyetograph and the area under the curve of the accumulated losses from the start of the storm up to any given time.

After initial losses have occurred, runoff flows overland toward a primary collection system such as a swale, alley or street gutter. The depth and velocity of overland flow, the slope of the land surface from the point of precipitation, and the extent of intermediate losses determine the rate at

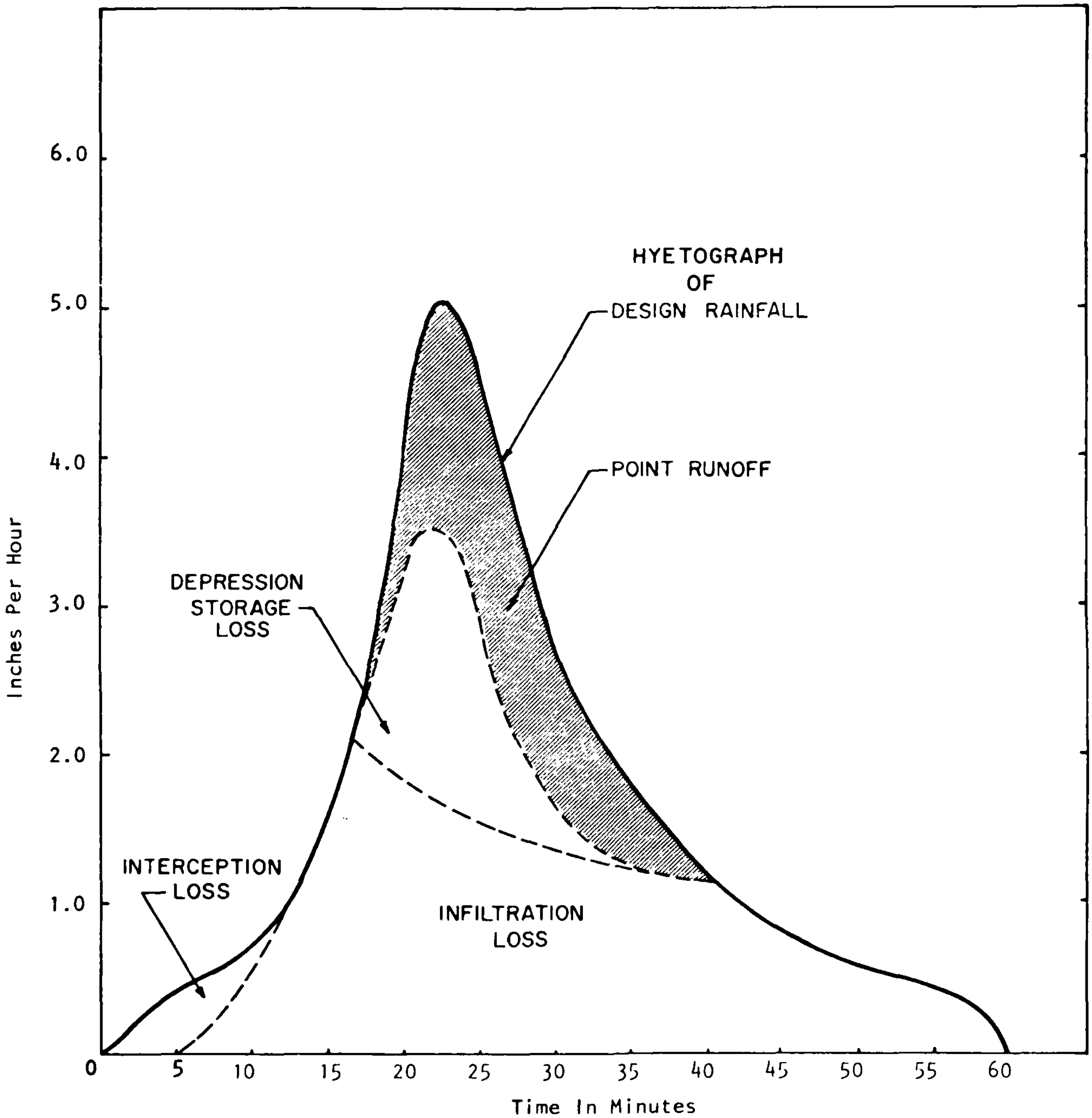


FIGURE 1-1

DETERMINATION OF RUNOFF FROM TURF AREAS

which runoff enters the primary collection system. The volume of surface runoff reaching this system is determined by subtracting total losses from the complete rainfall hyetograph. Total losses include initial infiltration, depression storage, and interception losses that occur at the time of precipitation, and similar intermediate losses which occur between the point of precipitation and the primary collection system. Because of intermediate losses, surface runoff enters the primary collection system at a rate less than the maximum rate at which rainfall becomes available for runoff.

Two methods for determining surface runoff and discharges in urban watersheds - the Barr Hydrograph Method developed by Barr Engineering Company and the more commonly used Rational Method - are described briefly in the next two sections. The discussions are followed by a summary of the advantages and disadvantages of each method.

BARR HYDROGRAPH METHOD

The Barr Hydrograph Method was developed by Barr Engineering Company in the 1950's for the analysis of urban runoff. Computerized in 1969, it has been used to determine stormwater discharges and volumes for a wide variety of projects. The basic theory of the method is to determine numerical values for the hydrological factors that affect peak discharges and storm runoff volumes.

The first step of the Barr Hydrograph Method is to determine the amount and intensity of rainfall for the selected design storm. The amount of rainfall in inches can be obtained from Technical Paper No. 40 (TP-40), a publication of the National Weather Service. A synthetic hyetograph showing rainfall intensity is then developed using TP-40 data and information obtained from a paper entitled, "Relation of Hourly Mean Rainfall to Actual Intensities" (Civil Engineering, May 1940). The hyetograph shape is similar to the storm pattern illustrated in a paper entitled "Synthetic Storm Pattern for Drainage Design" (C. J. Keifer and H. H. Chu, Proceedings of the American Society of Civil Engineers, August 1957).

Once a hyetograph is developed, numerical values are assigned to the major losses - infiltration, depression storage, and interception losses - that occur when precipitation reaches the ground. Interception losses are estimated using information such as that provided in Hydrology for Engineers (Linsley, Kohler, and Paulhus, 1949) and in ASCE Manual 37 (American Society of Civil Engineers, 1969). Infiltration losses for the Barr Hydrograph Method are determined using the Technical Manual of Engineering Practice No. 28 (American Society of Civil Engineers, 1949). As outlined in this manual, a standard infiltration curve is selected on the basis of soil types, antecedent moisture conditions, surface treatment, and ground cover. The curve is adjusted to account for antecedent precipitation. The amount of water held in depression storage depends on the slope and grading of the watershed. Infiltration, interception, and depression storage losses are deducted from the rainfall hyetograph to determine runoff for points within the watershed.

Point runoff is converted to area runoff in the Barr Hydrograph Method using principles of overland flow routing outlined in a paper entitled "Surface Runoff Determination from Rainfall Without Using Coefficients" (W. W. Horner and S. W. Jens, Transactions of the American Society of Civil Engineers, Volume 107). Synthetic unit hydrographs are developed for turfed and impervious areas for different slopes and overland flow lengths, and the percentage of each watershed corresponding to each of the various slope and flow length conditions is determined. Composite hydrographs of runoff are then calculated at collection points.

In the final step of the Barr Hydrograph Method, discharges are routed through the collection system of backyard swales, street gutters, and storm sewers. The channel routing method used is outlined in Technical Manual of Engineering Practice No. 28 (American Society of Civil Engineers, 1949). Discharges from various subwatersheds are combined in the channel routing process, with consideration given to travel time and channel storage. The hydrograph obtained at the outlet of the drainage system using this method gives both the peak discharge and the total volume of runoff reaching the outlet.

RATIONAL METHOD

The Rational Method is the most widely used method for determining peak runoff discharges used to design storm sewer systems. The method is effective if it is applied correctly. The basic formula for the Rational Method is Q = CIA, where Q = peak rate of runoff, C = runoff coefficient, I = average intensity of rainfall, and A = area of the tributary watershed. This formula assumes that the peak runoff rate is directly proportional to the average rainfall intensity for a period equal to the time of concentration for the watershed.

The average rainfall intensity (I) depends on the time of concentration (Tc), the time it takes for water to travel from the most remote point of a watershed to the outlet of the watershed. The time includes overland flow time and flow time in established drainage systems such as swales, street gutters, storm sewers, and ditches. Once the time of concentration is known, the average rainfall intensity can be obtained from published rainfall intensity-duration-frequency curves. If published curves are not available for the study area, curves can be developed using the National Weather Service's Technical Paper No. 40.

A problem with the Rational Method is the difficulty of determining the value of C, the runoff coefficient. The coefficient represents a number of variables including depression storage, interception and infiltration losses, ground slope, ground cover, surface treatment, channel storage, antecedent precipitation, soil moisture conditions, watershed shape, and overland flow velocity. The variable A (drainage area) in the Rational Method formula can be determined by field survey or by using topographic maps. Generally accepted design practices limit the use of the Rational Method to watersheds smaller than 5 square miles. Because the method does not provide information on total volumes of runoff, it is not particularly useful for studies requiring the design of stormwater storage basins.

COMPARISON OF THE BARR HYDROGRAPH METHOD AND THE RATIONAL METHOD

Knowledge of storm runoff volume is essential in areas where storage can be used to reduce the size of the storm sewer. The Barr Hydrograph Method is, therefore, preferable over the Rational Method because it gives both the peak

discharge and the total volume of runoff reaching a point of consideration; the Rational Method gives only the peak discharge. Attempts have been made to use the Rational Method to determine storm runoff volumes, but such attempts represent a misuse of this method. A second disadvantage of the Rational Method is that it considers only the part of the storm equal to the time of concentration while the total storm is considered in the Barr Hydrograph Method. In addition, it is necessary to investigate storms of various durations to properly size storage sites, a task easily done using the Barr Hydrograph Method but one not possible with the Rational Method.

The Barr Hydrograph Method and the Rational Method yield similar peak discharges when both methods are correctly applied to the same watershed. The Rational Method has a distinct advantage in terms of time required for computation, but the computation time for the Barr Hydrograph Method has been greatly reduced by computer application. The Rational Method is a simple and often used method of storm sewer design, but it requires an engineer with considerable experience and knowledge of hydrology to use it properly. Because the Barr Hydrograph Method requires an engineer to consider hydrological factors separately, the effects of small changes in variables are greatly reduced. The two major problems with the Rational Method are the selection of an accurate runoff coefficient (C) and the determination of the time of concentration (Tc).

RAINFALL FREQUENCY

Technical Paper No. 40, a publication of the National Weather Service, presents isopluvial lines of rainfall for the United States for storms of various durations and frequencies. The lines are developed from a statistical compilation of rainfall records.

STORMWATER STORAGE

The size and cost of pipes required for a storm sewer system depend upon the amount of land available to store stormwater. Because storm runoff comes in short bursts, the full capacity of storm sewers and channels is used for only a short time. If water from short bursts of runoff is collected in

storage basins and released over a longer period of time, smaller storm sewers, smaller channel sections, and smaller highway crossings downstream of storage areas can be used. The use of storage basins can substantially reduce the cost of drainage facilities if adequate storage volume can be secured and maintained. Because storage basins, like storm sewers, are used infrequently and for short periods of time, they can be designed as multipurpose facilities to serve other community purposes besides stormwater storage.

Storage basins are generally classified as "permanent ponds" or "inundation areas." Permanent ponds should be designed to serve secondary purposes for recreation or wildlife. A pond designed as a recreational area should be a minimum of 4 feet deep at normal water level to control emergent vegetation. Such a pond should also be designed to have a small water level fluctuation during periods of high runoff. Small fluctuations permit construction of roads and buildings close to the water and simplify the design of storm drainage facilities discharging into the pond. Large fluctuations in a pond's water level during the passing of a flood limit the possibility for improvements around the pond, thus decreasing the pond's value to the community.

Because inundation (temporary storage) basins generally have storm sewers passing under them to carry water from small storms, ponding does not occur during small storms. During larger frequency events, however, water is released from the basins at a rate slower than that at which it enters, causing water to collect in the inundation areas. The water is stored for a short period before being removed by the outlet pipe. Inundation basins should be designed to permit ponding only once or twice a year so they can also be used as parks or playground areas or left as open space. The construction of improvements below the anticipated flood level of a basin should be limited, and enough basin storage should be provided to prevent damage to surrounding structures.

Inundation basins should be used in a drainage system only when they can be properly located to serve as public facilities. The basins require considerable maintenance such as grass cutting and general cleanup, so normal use of the basin should justify this maintenance. Permanent pond storage basins require less municipal maintenance than do inundation basins since

private property can be extended to the edges of the ponds. Private landowners maintain the banks of permanent ponds in exchange for enjoying the recreational and aesthetic benefits of the pond. A permanent pond can be incorporated into a park or other public facility if its public value warrants such an act, thereby returning the maintenance responsibility for the pond to a city government. Lands used for inundation or permanent ponds must be controlled by the city to ensure maintenance of the storage facilities. Ordinarily, this means that the city must obtain ownership of the lands or flowage easements on the lands.

ATTACHMENT 2: STORMWATER STORAGE PRACTICES

EXISTING STORMWATER STORAGE PRACTICES

As indicated in Attachment 1, the size and cost of storm sewer systems can often be reduced by using temporary storage areas. Storm sewer systems are, therefore, often designed for carrying low flows with provisions for storing excess flows in marshes, low areas, or ponds. Many natural stormwater collection and detention areas exist on rural and undeveloped lands, but artificial ponds and inundation areas are often required where urban development has taken place. Some communities develop permanent detention ponds to concentrate needed storage volume within a minimum area. This approach minimizes the size of the flood-prone area, maximizes the area available for development, reduces the amount of land lost from tax rolls, and provides ponds in a neighborhood setting.

Another type of detention basin, the landlocked surface depression, can be used in addition to the inundation ponds and the permanent ponds discussed in Appendix 1. Water is lost from landlocked basins only by seepage and evaporation, unless outlets are provided to control high water levels. According to standard engineering procedures, stormwater storage systems are usually designed to accommodate a 100-year frequency flood without causing damage to occupied buildings.

FUTURE STORMWATER STORAGE PRACTICES

As development increases throughout a watershed, additional surface water storage systems are needed to cope with increases in the volume and rate of surface runoff. Options, other than storage ponds, that can be used to control runoff include expansion of inundated land and recreational areas, increased rooftop storage, and the use of the valve-controlled holding ponds in high density areas.

The inundation of recreational open-space areas has several advantages in that areas around the ponds can be landscaped to provide an environment

with potential for recreational use and development as a wildlife habitat. In addition, water quality problems associated with inundation areas are usually less than those associated with more permanent ponds. Inundation of recreational areas such as athletic fields, picnic areas, and similar open-space areas would not substantially interfere with the intended use of these areas if inundation occurred only several times in a 100-year period. Care must be taken, however, to design recreational areas to protect the turf from erosion. Several conceptual designs for low velocity inundation systems are shown in figures 2-1, 2-2, and 2-3. Marshes and bogs could be used to provide temporary flood control storage without impairing wildlife habitat or the aesthetic value of the areas.

The use of flat roofs to provide some rooftop storage should pose no structural problems for building design. Building codes generally require that flat roofs be capable of supporting at least 40 psf, a load equal to a water depth of over 7 inches. By installing restrictive outlets on roof drains, several inches of water can be temporarily stored on rooftops to decrease runoff rates. The structural safety can be maintained by providing free drain overflows for water depths exceeding the design storage depth. Designs should provide for a maximum detention time of 1 or 2 days to protect against leakage. Maintenance checks would be required to prevent clogging of the restricted drain inlet, but this inspection could be incorporated into the normal maintenance routine for a building.

Valve-controlled holding ponds provide flexible detention times and, as shown by experimental ponds in the Bassett Creek watershed near Minneapolis, Minnesota, they show promise in controlling water quality as well. Capital expense and operating attention are the two primary disadvantages of valve-controlled outlet detention ponds. Such systems could be feasible, however, for high density developments - large apartment complexes, office developments, and commercial or industrial centers - where the increased pollutant loading in stormwater runoff makes flood control and water quality improvement necessary. The capital expenditures on such projects probably would be minor compared to the total investment in the development, and regular maintenance personnel would be available to perform valve adjustments and system inspections.

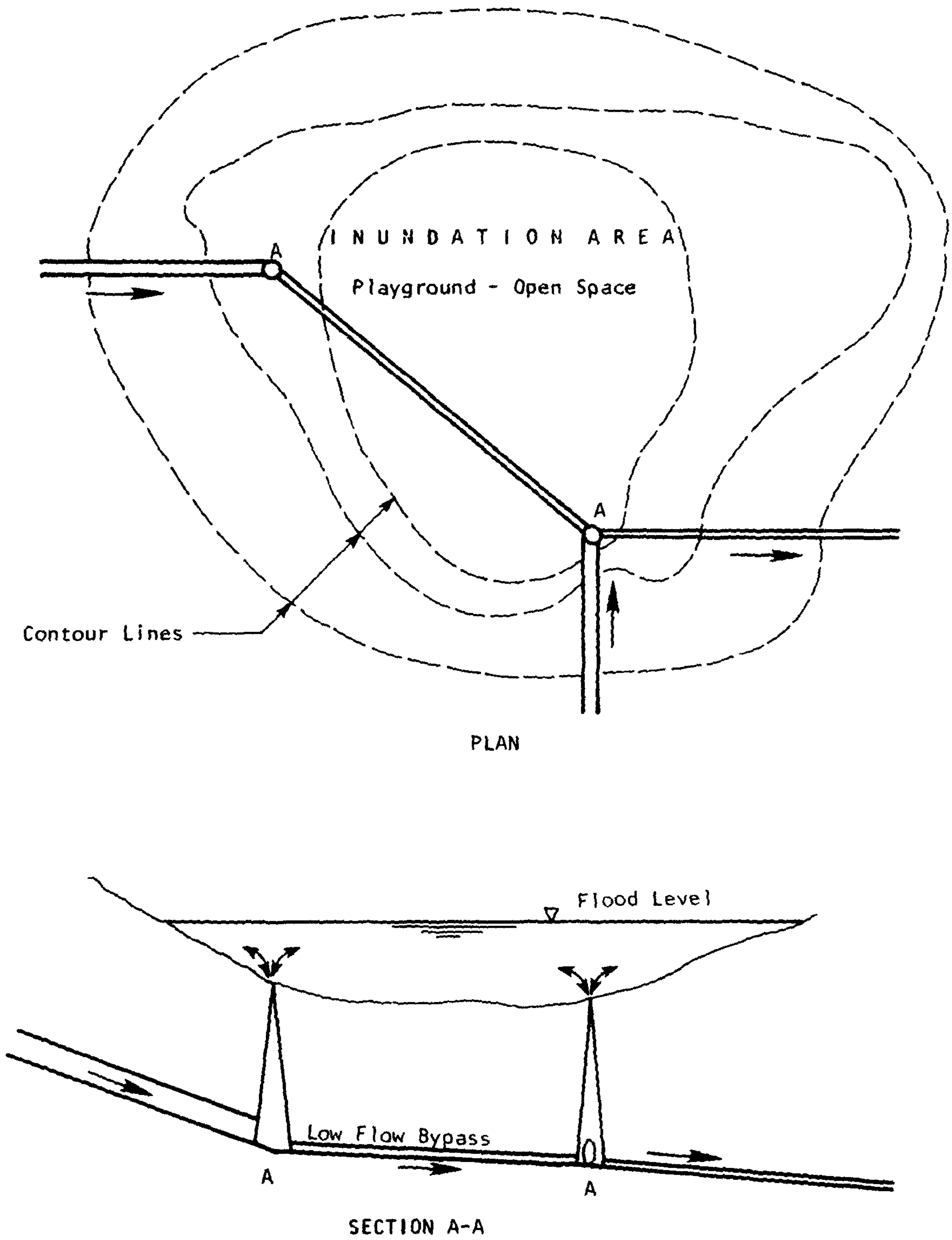


FIGURE 2-1

TYPE I INUNDATION AREA

Stormwater backs up into the inundation area during periods of high flow and drains back into the storm sewer system when flows through the system are reduced.

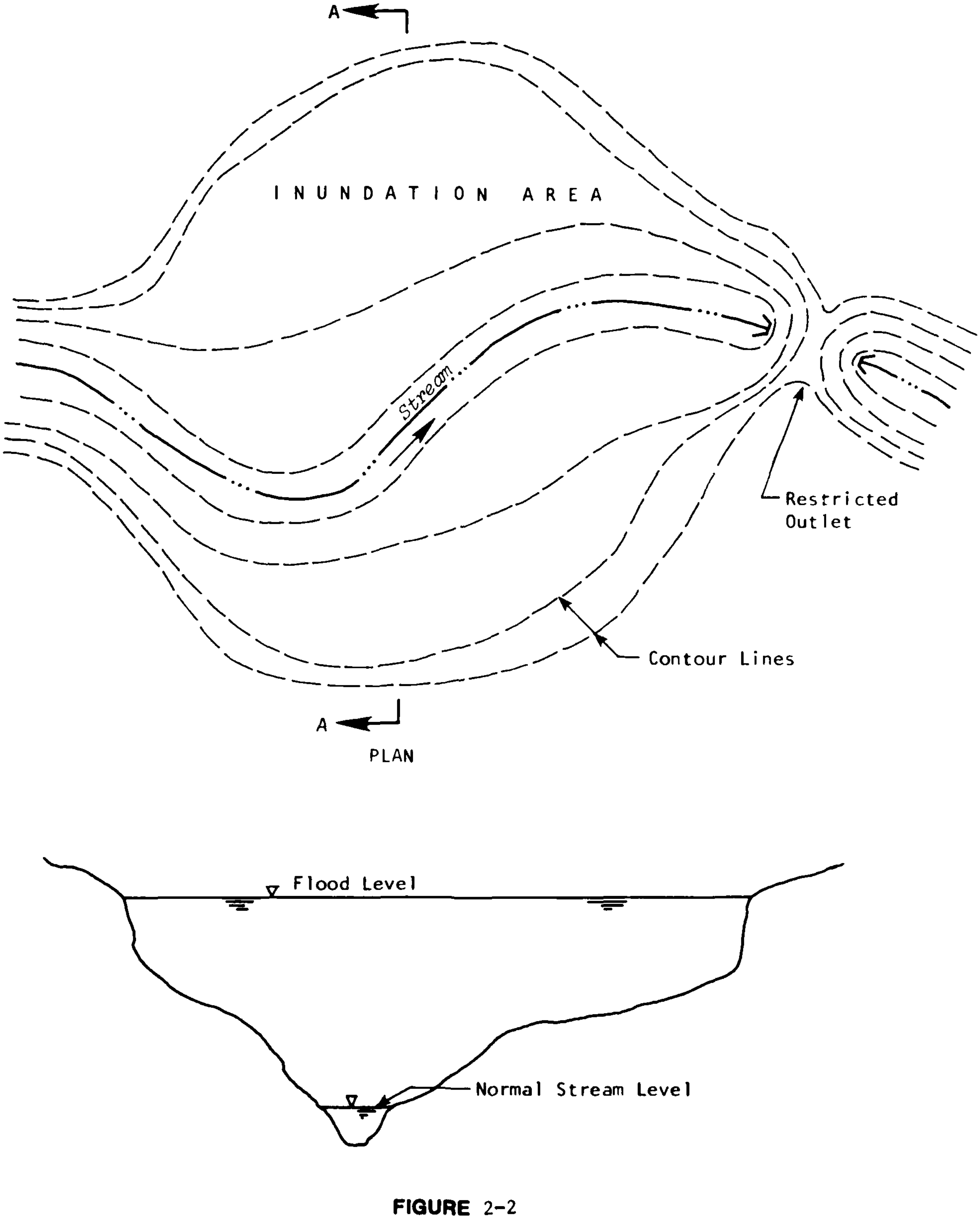
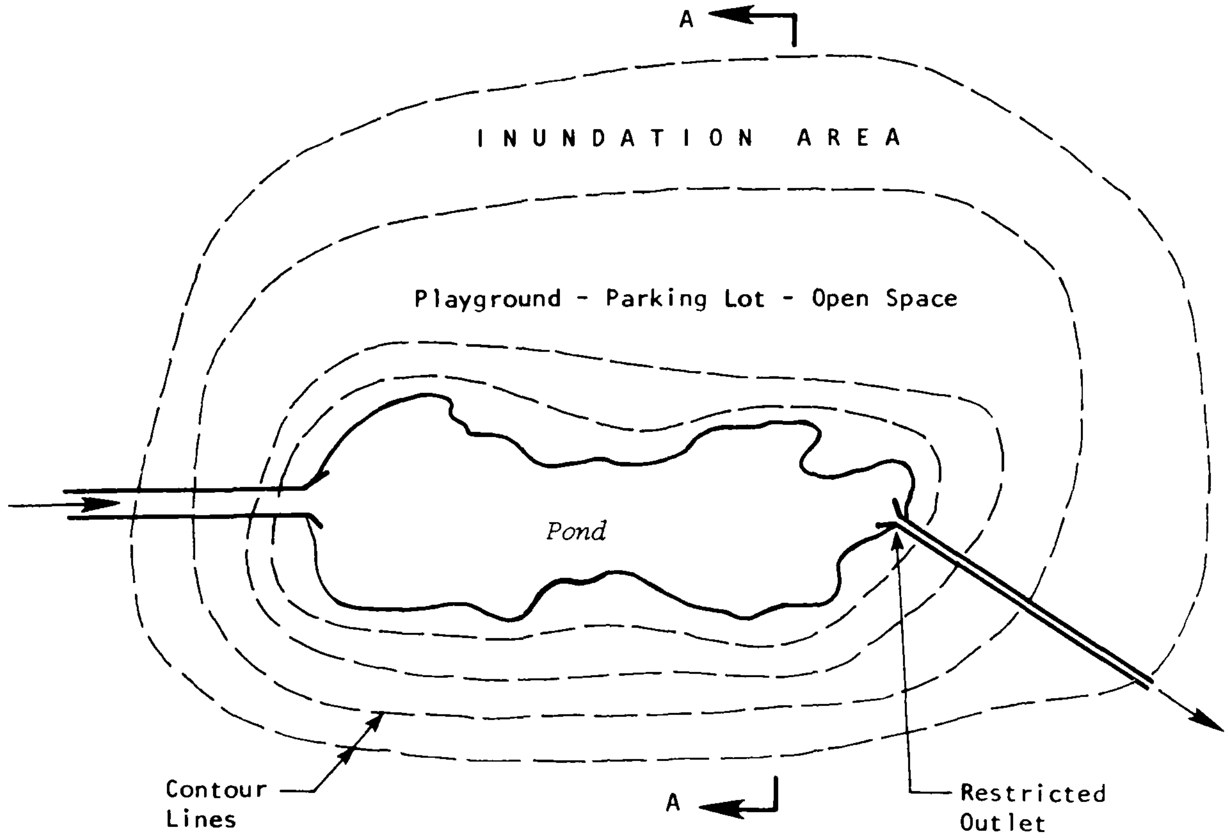


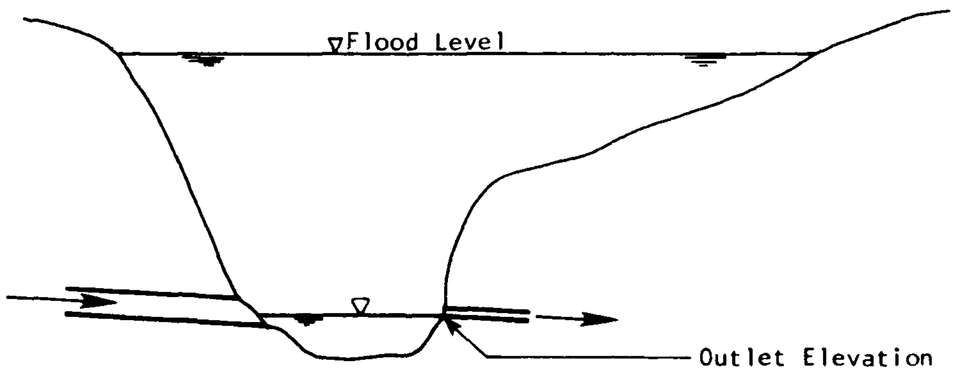
FIGURE 2-2

TYPE II INUNDATION AREA

Stormwater backs up and inundates the area behind the outlet during periods of high flow; the inundation area is gradually drained and stream flow returns to normal as flows are reduced.



PLAN



SECTION A-A

FIGURE 2-3

TYPE III INUNDATION AREA

Stormwater backs up behind the restricted outlet to increase the pond elevation during periods of high flow. The pond drains gradually to the outlet elevation as flows are reduced.

ATTACHMENT 3: MANAGEMENT OF RETENTION BASIN WATER QUALITY

INTRODUCTION

Runoff contaminants collect and concentrate in stormwater storage facilities, creating a sensitive trade-off situation whereby the contaminant loading of lakes and streams downstream of the storage facilities is minimized, but the ponds themselves experience a decrease in water quality. Silt accumulation, entrapment of a variety of contaminants, algal blooms, and an increase in the production of aquatic vegetation all contribute to poor water quality in runoff control ponds. If decreased water quality in ponds near residential and commercial establishments is not an acceptable trade-off for lake or stream improvements downstream, engineering and maintenance efforts may be required to control water quality in the storage ponds.

Several water quality management techniques have been developed to treat stormwater storage ponds; no single strategy is applicable to every treatment facility. Inflow treatment to partially remove runoff contaminants might be feasible at one site, for example, but problems associated with drainage layout, pond sizing, or other variables might preclude the use of this technique at another site. Decisions on management techniques should be site-specific, therefore, and they should be based upon the results of sound engineering, aesthetic, and economic analyses of possible sites. The two major types of water quality management techniques - inflow treatment and in-pond treatment - are discussed in the remaining paragraphs of this attachment.

INFLOW TREATMENT SYSTEM

Inflow treatment systems are based upon the principle of curtailing contaminant inputs - treating inflows before they are discharged into a pond. The curtailment of contaminant inputs is essential for effective long-term restoration of natural waters. A pond is a reflection of its watershed, and a restored pond will eventually return to a condition of poor water quality if contaminant inflows are not reduced. When control of contaminant inputs is

the only restoration technique employed, the rate and amount of pond improvement will depend on the quantity of contaminants remaining in the inflow and the exchange of nutrients or contaminants between the pond water and pond's bottom sediments. Improvements will be accelerated in ponds with shorter resident times (i.e., bodies which are being flushed more rapidly with higher quality water). Improvements will also occur more rapidly in deeper bodies where the transfer of materials from bottom sediments to water near the surface is inhibited by stratification and the absence of wind mixing. The recovery rate for shallow bodies will depend on the rate at which materials are internally recycled from the bottom sediments.

Removing contaminants from stormwater inflows to the degree necessary to restore a pond to high water quality can be an expensive and sophisticated operation involving solids disposal problems. Because of the "shock" nature of storm runoff (i.e., large, short-term runoffs), the large basins required for treatment are often used only on an intermittent basis. As an alternative to thorough treatment operations, partial treatment may be obtained using inflow sedimentation basins to remove settleable solids and other contaminants. The latter approach may have little or no effect on total phosphorus concentrations in runoff, however.

Although current flood control designs generally consider storms with an average return frequency of 100 years, water quality management systems can be designed for less extreme but more frequent runoff events. The treatment of peak flow rates for runoff events with return frequencies of 5 years or less will provide water quality control with a comfortable margin of safety in most cases, since biochemical systems in natural waters tend to follow annual cycles. Treatment of greater flow rates is generally neither economically nor physically feasible. Systems can be designed so that runoffs exceeding the 5-year frequency event bypass inflow treatment devices and discharge directly into stormwater storage areas.

Inflow treatment at a storm sewer outlet to a flood control pond should focus on material removal and treatment with minimum intrusion into the pond. The aesthetic value of storage ponds and limitations on space available for the treatment facilities will be design considerations. Simple structures

capable of removing bulky solids, grit, and floating materials are considered to be the most practical inflow treatment systems.

SOURCE TREATMENT SYSTEMS

Source treatment systems are based upon the principle of removing solids and stormwater contaminants at their source before they are picked up by storm runoff. General community cleanup is a major type of source treatment according to this definition, and Minneapolis and other cities have learned that one of the most valuable approaches to general community cleanliness is regular street sweeping. Street sweeping improves the quality of both the terrestrial and the aquatic environments, and the cost of the procedure is usually less than the cost of inflow treatment systems.

Research shows that conventional mechanical sweepers remove only about 50 percent of street surface contamination and about 20 percent of total phosphorus under optimal conditions. Because of recent technical advances in sweeping machinery, however, new designs may be more successful in removing fine particles on street surfaces. These newer machines have a greater capital cost than do conventional mechanical sweepers (about $40,000 vs. $20,000), but they appear to have much lower operating and maintenance costs and greater versatility. Available data indicate that once-a-week sweeping is likely to be effective for most cities, although any increase in sweeping frequency will help.

Citizen participation can also be enlisted to eliminate nutrients and contaminants at their source. Phosphorus and other contaminants are introduced into storm runoff by home car washing, for example. A study of Minneapolis lakes suggests that positive results can be achieved by having residents refrain from placing leaves and other debris in street gutters. Yard rubbish could be collected periodically by city crews in a manner similar to, but less frequently than, garbage collection (monthly, for example). Individual and community composting programs, such as Hennepin County's leaf recycling program, may also help to reduce nutrient runoff from lawn maintenance.

In a Minneapolis lake study, it was also found that annual phosphorus fertilizing is often unnecessary since sufficient phosphorus is already available in most residential lawn soils. Low-phosphorus fertilizers could be used to reduce nutrient concentrations in runoff from residential lots, or the loss of nutrients might be reduced by using organic fertilizers which provide an adsorbent matrix. The usefulness of the latter technique has not yet been determined.

EFFECTS OF WINTER ICE CONTROL EFFORTS

The effect of sodium chloride (street salt) on lakes has been investigated in recent years, but uncertainties remain about the importance of this effect. Elevated sodium and chloride concentrations resulting from street salting for ice control have been found in snowmelt runoff, however. The concentrations at which sodium or chloride become toxic to plants and animals are influenced by concentrations of other materials and the sensitivity of local plants and animals. High salt concentrations in runoff may cause leaf burn, defoliation, and plant death. Research also shows that many blue-green algal species favor or require high concentrations of various salts, putting other algae at a competitive disadvantage. The latter point is important, since blue-green algae are frequently responsible for the most noxious effects of eutrophication. Other studies show that sodium concentrations can result from the breakdown of agglomerated silt and clay into more finely divided soils that settle more slowly. A 1974 study of lakes in the Minneapolis-St. Paul metropolitan area indicated that the clearest lakes had the lowest concentrations of chloride and the most turbid lakes had the highest concentrations of chlorides.

ATTACHMENT 4: SAMPLE DRAINAGE ORDINANCE

CITY OF ______________ ORDINANCE NO. _____

An ordinance to implement an overall urban drainage master plan; to establish an Urban Drainage Management Fund; and to provide for the payment of certain charges to the Fund by persons platting property and/or developing residential, commercial, industrial, or institutional property which increases stormwater runoff.

The City Council of the city of ______________ does hereby ordain:

Section 1: Statement of Policy

It is in the best interest of the public to protect against uncoordinated and unplanned land development affecting marshes, swamps, wetlands, drainageways, lakes, and watercourses within the city. Such development, if allowed to continue uncontrolled, will cause damage to public and private improvements through inundation by floodwaters; will create a need for the construction of expensive storm sewers and other public projects; will cause the permanent destruction of natural resources; will result in the loss of existing and potential water detention and retention facilities, open space areas, and wildlife habitats; and will impair the quality of public and private water supplies.

The general purpose of this ordinance is to permit and encourage a coordinated land and water management program in the city of ____________. The specific objectives of the ordinance are to:

(a) Reduce danger to health and provide safe and sanitary drainage by protecting surface water and groundwater supplies from impairment resulting from incompatible land uses.

(b) Reduce the financial burdens imposed on the city of ______________, on downstream communities and on individuals

therein by the occurrence of frequent flooding and overflow of water on lands.

(c) Permit and encourage planned land development which will not alter the flow of floodwater or increase danger to life or property.

(d) Permit and encourage land uses compatible with the preservation of natural ponds, marshes, and other potential detention and retention areas which are a principal factor in maintaining uniform rates of water flow in the natural drainage system.

(e) Encourage the design and implementation of a stormwater management system which minimizes the entrainment of pollutants and provides for reasonable control of stormwater runoff before the runoff reaches the natural drainage system.

(f) Provide sufficient land area to carry abnormal stormwater flows in periods of heavy precipitation to prevent the needless expenditure of public funds for storm sewers and flood protection devices that can be avoided with orderly planning.

(g) Prevent development in areas determined unfit for human usage because of the danger from flooding or the existence of unsanitary conditions or other hazards.

Section 2: Definitions

(a) "Owner" means any person, firm, or corporation.

(b) "Plan" means the city's Urban Drainage Master Plan.

(c) "Development" means: platting property under the Subdivision Ordinance; commercial, industrial, and institutional construction activity that increases stormwater runoff; and residential construction activity involving more than _____ units that causes an increase in stormwater runoff.

(d) "Cost basis per acre" for the acquisition and physical development of stormwater retention areas or conveyance facilities. This amount shall be computed on a per acre basis and it shall be determined by and revised by resolution of the City Council.

(e) "Detention" means the temporary storage of water.

(f) "Retention" means the relatively permanent storage of water.

(g) "Stormwater management" means a system of structural or non-structural measures which controls the increased rate and volume of surface water runoff caused by development. Stormwater management has the effect of maintaining existing patterns of flood magnitude and frequency.

(h) "Fund" means the city's Urban Drainage Management Fund.

Section 3: Establishment of Fund

There is hereby established and created a fund designated as the Urban Drainage Management Fund.

Section 4: Purpose of Fund

The purpose of the Fund is to provide for the acquisition and development of stormwater detention and retention areas within the city of ________________.

Section 5: Applicability of Fund

Any owner who increases stormwater runoff by platting and/or developing commercial, industrial, residential or institutional property shall, at the option of the city, either provide on-site storage for that runoff, contribute cash to the Fund on a cost basis per acre as determined by the city, or provide a combination of on-site storage and a cash contribution. Whenever possible, the city will encourage an overall system approach or watershed approach

rather than an individual approach to the development of stormwater management systems.

When it is the opinion of the City Council that any owner platting property and/or developing commercial, industrial, residential or institutional property can or should provide total on-site retention of the increase in runoff generated by the development, said owner shall provide total on-site retention in a manner satisfactory to the city and no cash contribution to the city shall be necessary. The facilities will be designed by the owner in accordance with criteria set forth in the city's Urban Drainage Master Plan.

When it is the opinion of the City Council that any owner platting and/or developing commercial, industrial, residential or institutional property cannot or should not provide total on-site retention of the additional stormwater runoff generated by the development in a manner approved by the city, such an owner shall pay to the city an amount on a cost basis per acre determined by computing the percentage of the peak discharge or increased volume that can be attributed to the proposed improvement as determined from the city's plan.

If partial on-site storage is approved by the City Council, the on-site storage shall be provided by the owner in a manner satisfactory to the city. The percentage of the payment required by the owner to the city shall be computed by determining the net increase in the peak discharge or runoff volume after any approved on-site storage is provided.

Amounts due to the city for any developments shall be paid prior to the issuance of any permits for the development unless an alternative method of payment is approved by the City Council.

Section 6: Fund Disbursements

Fund receipts shall be used only for the purpose of acquisition and/or development of stormwater detention or retention areas or conveyance facilities within the city, including debt retirement. The City Council may by a majority vote, however, declare said funds surplus and expend said funds for

water-related management projects not confined to the city's corporate limits.

Section 7: Penalty

Any person, firm or corporation who violates any portion of this ordinance shall be guilty of a misdemeanor and shall, upon conviction thereof, be subject to a fine of not more than $300 or imprisonment for not more than 90 days or both.

Section 8: Exemption

Any development which, because of its size or location, will have no measurable effect on stormwater discharge or runoff volume may be exempt from providing on-site storage or contributing to the Fund, provided the owner can demonstrate to the city that the effect of the proposed development on storm runoff or discharge is negligible.

DATE
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